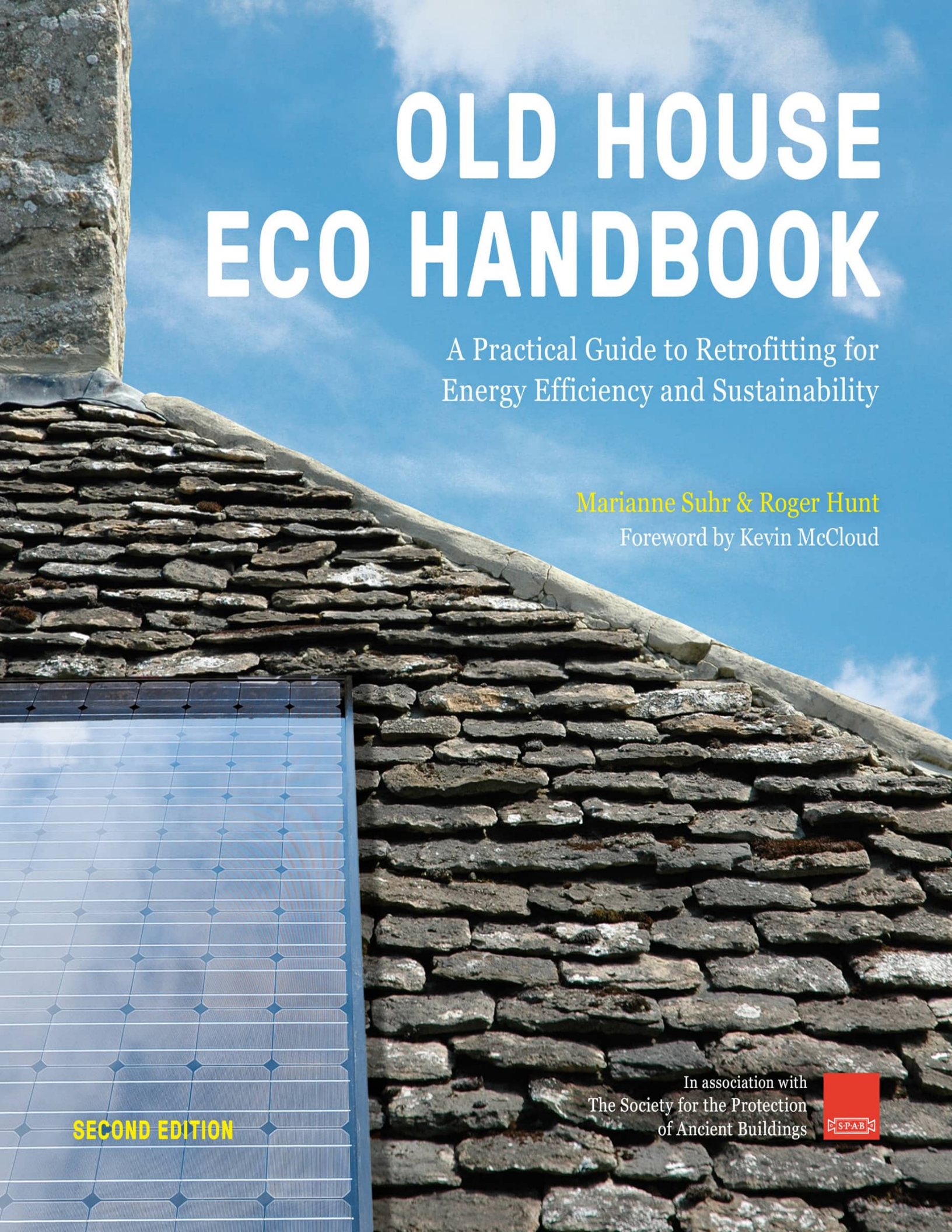

OLD HOUSE ECO HANDBOOK

A Practical Guide to Retrofitting for Energy Efficiency and Sustainability

Marianne Suhr & Roger Hunt
Foreword by Kevin McCloud

In association with
The Society for the Protection of Ancient Buildings

SPAB

SECOND EDITION

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WHITE LION PUBLISHING

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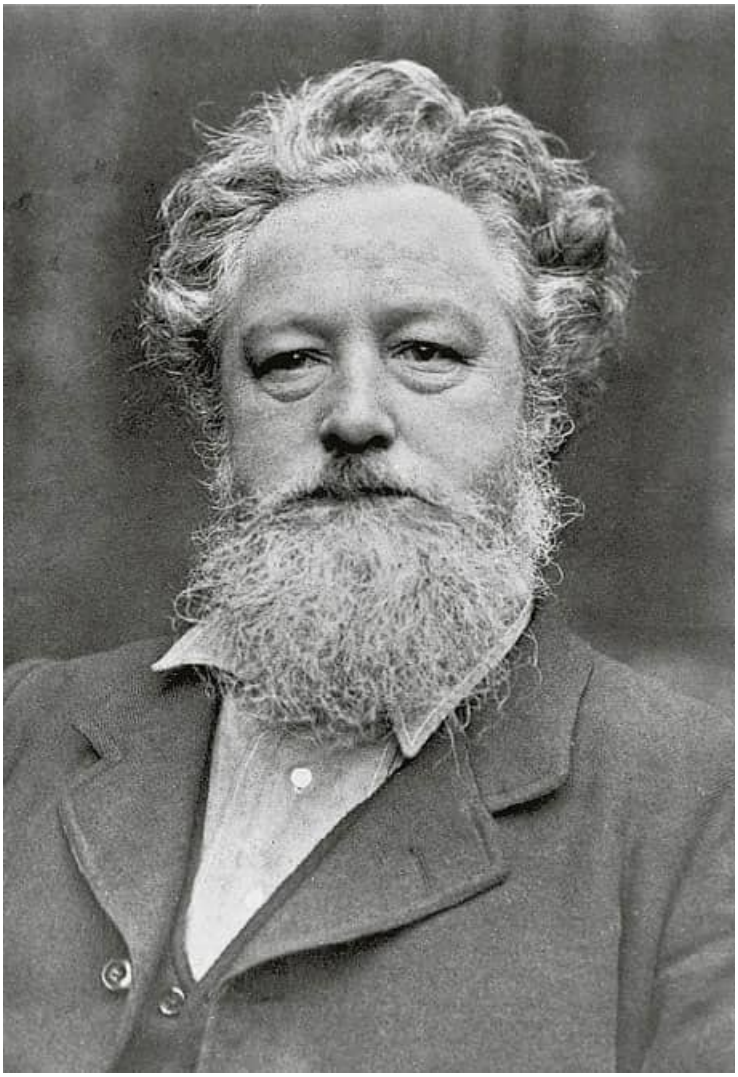
THE SOCIETY FOR THE PROTECTION OF ANCIENT BUILDINGS



William Morris (1834–96), co-founder of the Society for the Protection of Ancient Buildings.

The Society for the Protection of Ancient Buildings was co-founded by William Morris in 1877 to counteract the highly destructive ‘restoration’ of medieval buildings being practised by many Victorian architects. Today it is the largest, oldest and most technically expert national pressure group

fighting to save old buildings from decay, demolition and damage; its philosophy is set out in The SPAB Approach.

Members include many of the leading conservation practitioners as well as home owners, living in houses spanning all historical periods, and those who simply care about old buildings. Thousands of buildings survive which would have been lost, mutilated or badly repaired without the SPAB's intervention. Indeed, many of the most famous structures in Britain are cared for by some of the thousands of people who have received the Society's training.

The SPAB is a charity representing the practical and positive side of conservation, not only campaigning but educating and offering advice. Courses are run for building professionals and homeowners and information is available in the form of publications and a telephone helpline manned by experts.

A firm set of principles backed by practical knowledge, accumulated over many decades, is at the heart of the Society's approach to repair. Misguided work can be extremely destructive and the skill lies in making repairs with the minimum loss of fabric and so of beauty and authenticity – old buildings are not best preserved by 'restoring' them to make them new and perfect.

Remember, maintenance is the most practical and economic form of preservation. Buildings cannot be made to last forever but, through the conservative approach advocated by the SPAB, they will survive as long as possible and suffer the least alteration.

More information about the Society's work and the help it can offer is available at www.spab.org.uk.

FOREWORD

Kevin McCloud, author, broadcaster and designer.

There are some 26 million homes in Britain, most of them as well insulated as a rabbit hutch, most of which will still be in existence in 2050. Half a million of them are listed; countless numbers sit in conservation areas and, very roughly, one fifth of our dwellings were built before 1919.

Collectively, the buildings we live in are responsible for more or less 26 per cent of Britain's carbon emissions. Now, you may be among the dwindling number of people who believe that increased levels of atmospheric carbon dioxide have got nothing to do with human activity and that we can do

nothing about that. You may cry humbug to the Greens among us and eschew words such as sustainability and eco as mere baubles of conversational fashion. But I doubt that, because you've already picked this book up.

In any case, it doesn't require a lifetime membership of Greenpeace to appreciate that the planet's resources are finite, that the world population is growing beyond sustainable levels and that our homes gobble energy to keep us warm and fed. Generally speaking, the older and larger our homes are, the more energy they consume. Any owner of an historic home will be sensitised to the cost of this and to the volatility of energy markets just by reading their electricity, gas or oil bills. Indeed, some of the nation's more august historic homeowners have responded over the past ten years by investing in low-carbon and independent technologies such as solar photovoltaic and biomass boilers to reduce the sheer cost of heating and maintaining their properties.

The rest of us shiver at the capital cost of a wood-pellet boiler with auger-feed and ash-compacter and just don another pullover. So three green cheers for this book, which mixes an erudite analysis of the latest building science with practical advice and demonstrations of best practice. It behoves any proud carer of an old home to arm themselves with an outline understanding of dewpoints, interstitial condensation and U-values, and – do not fret, dear Reader – these are all admirably and sometimes even entertainingly explained and illustrated here. More hurrahs! Moreover, they are helpfully framed in the context of what is good conservation practice, of the need for reversibility and for the retention of our buildings' narratives. These ideas are part of the bedrock of the Society for the Protection of Ancient Buildings, this book's co-publisher.

Britain's older housing is immensely varied, dependent on vernacular styles and a vast range of materials that give the historic built environment of the British Isles a great deal of charm and diversity. We can't just slap insulation board over every home in the country and then apply a coat of efficient German render. Our older homes need a delicate touch and tailored solutions that will involve professional architects and historic building

surveyors but which ultimately will rely upon the informed enthusiasm of homeowners.

This book treads the brave and narrow path between the slippery pitfalls of the eco agenda on the one hand and the treacherous skewers of conservation on the other. Green building and traditional building may seem likely bedfellows – they share a love of natural, breathing materials such as lime mortar and doglick; but this common interest is a narrow one and in truth there is a great deal of compromise to be forged, between their separate demands, on any building conservation project. This book is intended, lucidly and comfortably, to guide you along that path.

KEVIN MCCLOUD

ADVISORY NOTE

Please note that the information given here is based on the best current practice. But every building is different, and so specific recommendations or suggestions may not necessarily be relevant in every instance. They should not be applied automatically. If you are in any doubt, do seek suitably experienced professional advice. This also relates to the photographs and illustrations which indicate an approach, but which should not be treated as a guarantee of the correct method in every set of circumstances. Site safety and building methods shown in the photographs are not necessarily best practice or endorsed by the authors or the SPAB.

Retrofitting old buildings is a new and constantly evolving science. Generally, natural and breathable products are favoured but as every situation is different the consequences of any intervention cannot be predicted with certainty. Before applying any method, material or detail, always seek the advice of the manufacturer or supplier or check with a qualified professional as to whether or not it is appropriate to your particular building.

Research is a vital part of any work to an old building. The SPAB website, bookshop and technical advice line are geared towards helping homeowners, craftspeople and professional advisers and can provide the latest information. For this reason, lists of organisations, suppliers and publications that might quickly date have not been included here.

Historic environment consents

Given the vast number of different areas of work covered in this book, it would be difficult, if not repetitive, to draw attention to all the circumstances in which consent may be required to make changes. This omission does not mean that the matter should be disregarded. Quite the contrary; the UK has strict laws which protect historic buildings, areas, sites and landscapes and it is in your interest to adhere to these.

Before beginning any work of repair, alteration or development to your house, any structures within its grounds or the site on which it stands, it is

essential to check with your local planning authority whether any consent will be needed. In the case of all listed buildings, do remember that the interior as well as the exterior is protected, and that the listing may extend to ancillary structures within the main building’s curtilage (the land attached to it). When consent is granted, work must follow the approved drawings exactly, as well as any conditions that have been imposed.

PREFACE

Old House Handbook was published in 2008 with the aim of providing 'simple "nuts and bolts" guidance' on the basics of repairing old houses. It remains a bestseller, helping both those maintaining old buildings and those taking on a 'wreck' in need of major work. It now seems incredible that we made little mention within its pages of the need to improve the thermal efficiency of old houses but, at that time, thoughts of energy-efficient retrofits to buildings of any kind were in their infancy.

With the publication of *Old House Eco Handbook* five years later, we sought to rectify the omission. As a companion volume to *Old House Handbook*, it has been popular in its own right but, once again, thinking has moved on. Much has been learnt about retrofitting, new materials have emerged to help the process, and the correlation between retrofitting and the unintended consequences that can result is better understood.

In writing this new and thoroughly updated version of *Old House Eco Handbook*, we have attempted to bring together a large body of knowledge. This has been gained from both research and the practical experience of professionals, suppliers, tradespeople and homeowners, retrofitting buildings of all periods and styles.

Undertaking a retrofit can be a challenging, exciting and energy efficient thing to do; but it is not without its pitfalls. We always urge caution, the health of the building and its occupants must be considered above all else. Our aim within these pages is to share practical advice that achieves a balance between caring for an old building and a sensitive retrofit that creates a comfortable, sustainable home to be enjoyed by many future generations.

MARIANNE SUHR
ROGER HUNT

01 | OLD HOUSES CAN BE GREEN

William Morris, founder of the Society for the Protection of Ancient Buildings (SPAB), said: ‘We are only trustees for those that come after us.’ He was referring to buildings, but today this statement could equally apply to the wider environment. Our challenge is to balance the need to be sustainable with caring for our built heritage, without destroying what is important.

Old houses are special, be they medieval and timber framed, part of an Edwardian brick terrace or any period or style in between. Retrofitting them to improve energy efficiency is not about quick fixes. Many fall into the ‘hard to treat’ category, most commonly because they have solid walls of traditional construction that cannot easily be modified without unintended consequences. They can be difficult to insulate for several reasons: moisture movement and ‘breathability’ may be affected, historic fabric needs to be retained or there is a risk of spoiling their appearance and character.

Improving a building's thermal efficiency is important, but care must be taken not to create problems for the future.

Old buildings frequently possess values associated with being 'eco' or 'green', as they are built with natural, often local, materials and employ reusable and easily repairable components. They also represent an investment in craftsmanship and design and commonly have a high thermal mass, which helps to prevent summer overheating. In short, they are a valuable resource for the future and have a significant role to play in maintaining communities, helping to underpin them with character and aesthetic interest.

Well-executed retrofits reinforce these qualities and have the potential to cut carbon dioxide (CO_2) emissions by improving the buildings' energy efficiency. Doing this potentially also reduces fuel poverty and ill health, as well as helping to avoid buildings being lost through redundancy or dilapidation. But we must take care in the process: unless we fully understand how an old building works there is a very real risk that, at some

point in the future, we may find ourselves rectifying problems created by the use of ill-judged techniques and materials.

SUSTAINABILITY

When retrofitting, we must consider sustainability in its broadest sense. To use the key statement coined by the Brundtland Commission in 1987, sustainable development is about ‘development that meets the needs of the present without compromising the ability of future generations to meet their own needs’.

Just like classic cars, old houses can continue to be useful if well maintained.

To live sustainably is to tread lightly on the earth. It means living within our means in terms of resources; minimising pollution to the air, soil and water;

and respecting the biodiversity of the wider environment. Scrutinising the life cycle of products, eliminating carbon emissions resulting from intensive energy use, and reducing our dependence on fossil fuels are all part of this, as is retaining and creating strong communities and pleasant places to live.

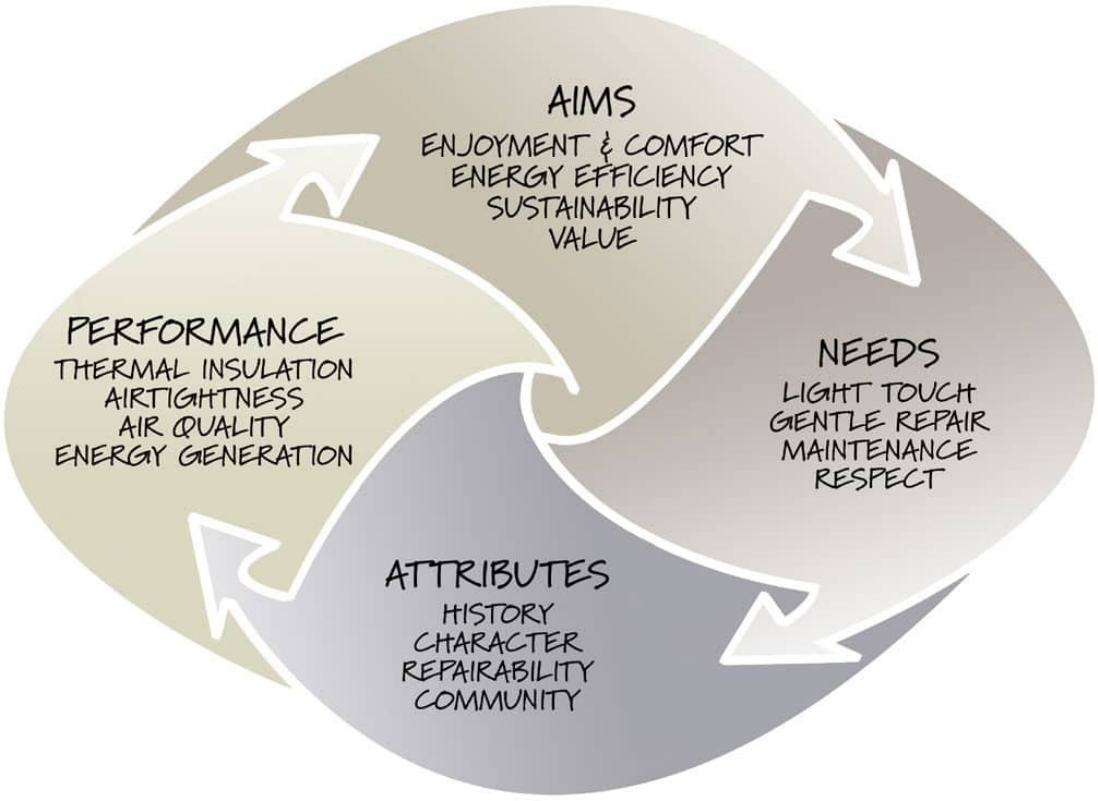
The special qualities of an old building, such as those seen in this house, can easily be destroyed if they are not appreciated.

The most successful and sustainable retrofits are those in which everyone involved appreciates that, from conception to delivery, the work requires a multifaceted approach and understanding. Retrofitting an old building

sustainably is about making it more enjoyable and comfortable to occupy. It involves improving its energy efficiency and enhancing the overall value of the property in terms of utility, as well as aesthetically, financially and environmentally.

To achieve these aims, we need to understand the way a building was constructed and how the materials from which it was made perform. New work requires a considered approach and a light touch. Regular maintenance and gentle repair are vital, while all work must be respectful of the attributes that make a building special: its history and character, its repairability and the part it plays in the wider community.

Increasing the building's performance is vital to any retrofit and will almost certainly involve improving thermal insulation and airtightness and ensuring good indoor air quality; it may also include providing a means of generating energy.



The virtuous circle of sustainability relating to old buildings.

When combined, these constituents create a virtuous circle and, if considered and implemented together, the overall effect is to increase the sustainability of the whole.

UNDERSTANDING OLD BUILDINGS

Old buildings have a subtle, intangible, often hard-to-define quality or character. This is related to texture, irregularity and the patina of age – it may be seen in a brick floor worn by centuries of use, gently undulating plasterwork or a lopsided window resulting from the slight settlement of a wall. Once disfigured or destroyed, such subtleties can never be reinstated and their aesthetic and historic value is lost forever. Equally, the materials and techniques used in the construction of old buildings are special and have qualities not found in the mass-produced products of today.

When damage occurs, it is frequently through ignorance rather than deliberate intent. Many people see themselves not just as owners or occupants but as guardians of old buildings and, by carefully balancing the needs of today with those of the past, help ensure their houses have a viable future. The golden rule is to do as little as possible and no more than is necessary.

Repair, not restore

Caring for old buildings is about preventing any unnecessary loss to the building's fabric. The general approach to building conservation was established in 1877, when William Morris founded the SPAB. In its manifesto he set out a philosophy of repair rather than restoration, which guides the Society's work to this day.

Repair is based on the principle of mending buildings with the minimum loss of fabric and, in so doing, keeping their character and authenticity. Contrary to this, restoration means work intended to return an old building to a perfect state – in other words, putting things back to how they were, or how we think they were, rather than preserving them as they are now with all their wonderful marks of time and history. Restoration is generally highly destructive and, as Morris states in the manifesto, 'a feeble and lifeless forgery is the final result of all the wasted labour'.

Putting the philosophy outlined by Morris into practice means, for example, repairing only the decayed bottom rail of an original sash window rather than replacing the whole sash. The aim is not to hide imperfections such as bulges, bows, sags and leans, but rather to respect and enjoy them. An approach that involves SPAB-minded conservative repair is likely to be the least costly in the longer term, the greenest and the most enduring; it will probably also maximise the future value of your house. This book's companion volume, *Old House Handbook*, explains the practicalities of following these principles.

This sash window has been carefully repaired, and the rotten cill replaced.

ESSENTIAL DIFFERENCES

The building techniques that we know today began to be introduced in the second half of the nineteenth century, with cement-based mortars, renders and plasters coming into general use by the late 1940s. These techniques rely on impervious outer layers, cavity walls and barriers against moisture; approaches that are totally incompatible with traditional solid-wall

construction, which works in a very different way. Additionally, there has been a propensity for creating hermetically sealed interiors with central heating and little air movement which, if not correctly managed, will be at odds with the way an older building functions.

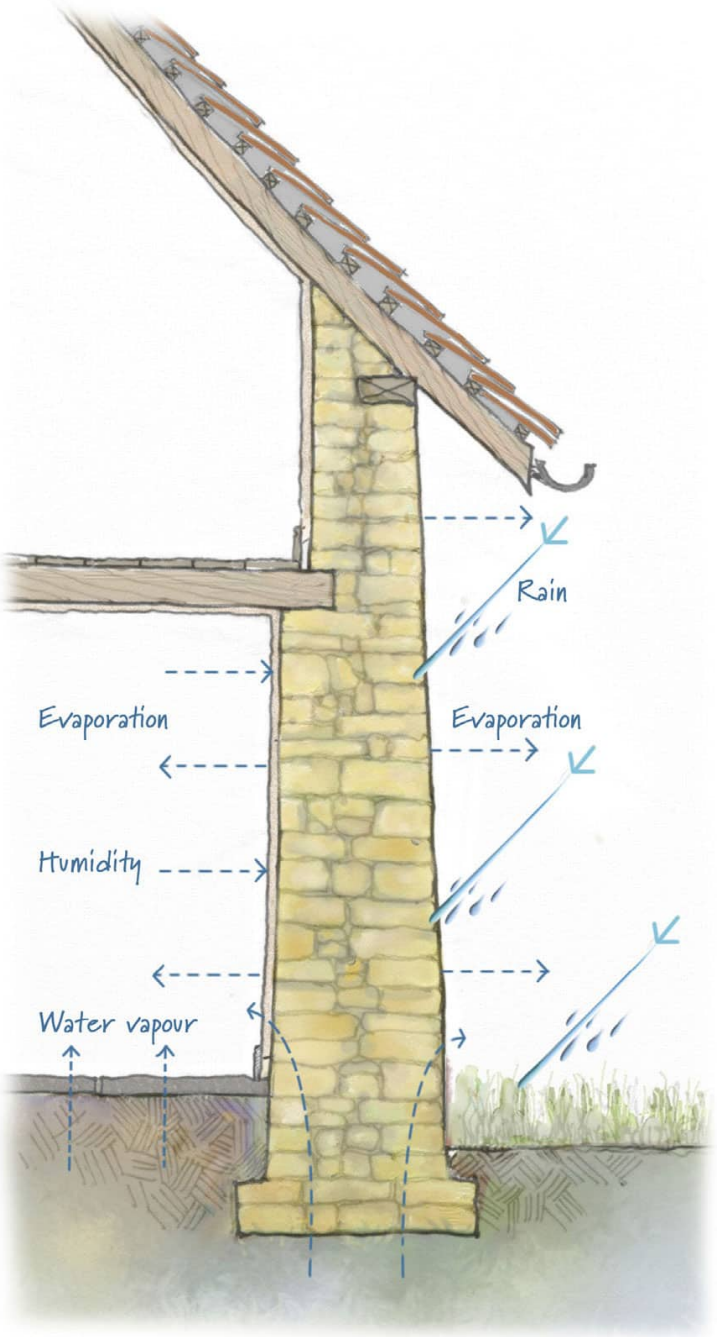
Cavity walls, though occasionally used by the Victorians, became popular in the early twentieth century and have since been adopted as a standard construction method. Until that time, most buildings had solid walls, and this older form accounts for an estimated one out of every five homes in the UK. In solid-walled, traditionally built houses, the bricks and stones were generally bonded with weak and permeable mortars made of lime and sand, or sometimes just earth. When external walls constructed with these materials were rendered, lime render and limewash were used, allowing the structure to ‘breathe’ (See Understanding breathability, shown here). When it rained, moisture was absorbed a few millimetres into the external surface but was able to evaporate when the rain stopped, helped by the drying effects of the sun and wind.

Inside, walls were plastered with lime or clay and finished with simple breathable paints such as limewash or soft distemper. Any excess internal humidity from washing and drying, cooking and human activity was dispersed by way of open flues and draughts, or absorbed by the breathable surfaces that acted as moisture buffers. In addition, a kitchen range and open fires drew air through the house and kept internal surfaces at a steady temperature. Provided such buildings are properly maintained, the structures remain essentially dry and in equilibrium.

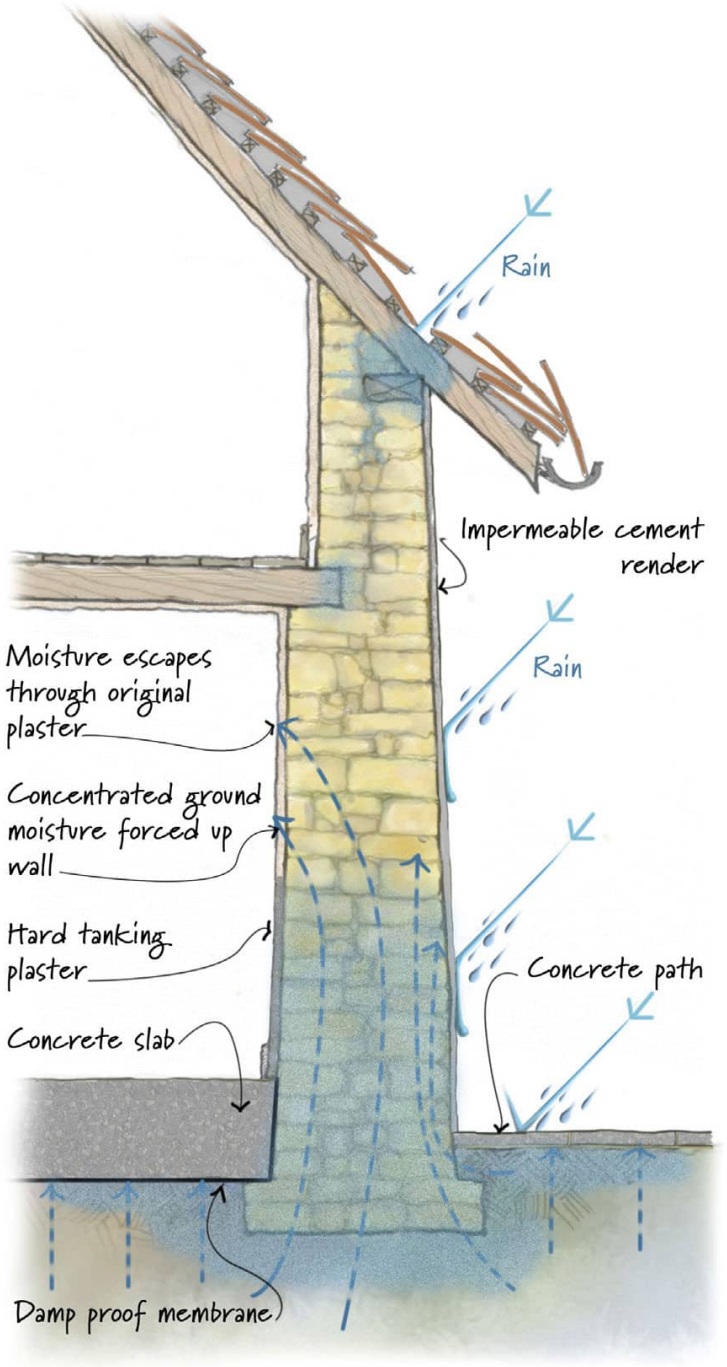
The early twentieth century saw the final flourish of traditional building techniques.

In recent times, the understanding of how traditional solid walls work has become confused and those working on old buildings have sometimes attempted to apply modern techniques and impermeable materials to breathing structures. Cement renders, along with ‘plastic’ paints, waterproof sealants, damp-proof membranes and even insulation materials, can act as barriers to the building’s natural ability to breathe. This is where trouble

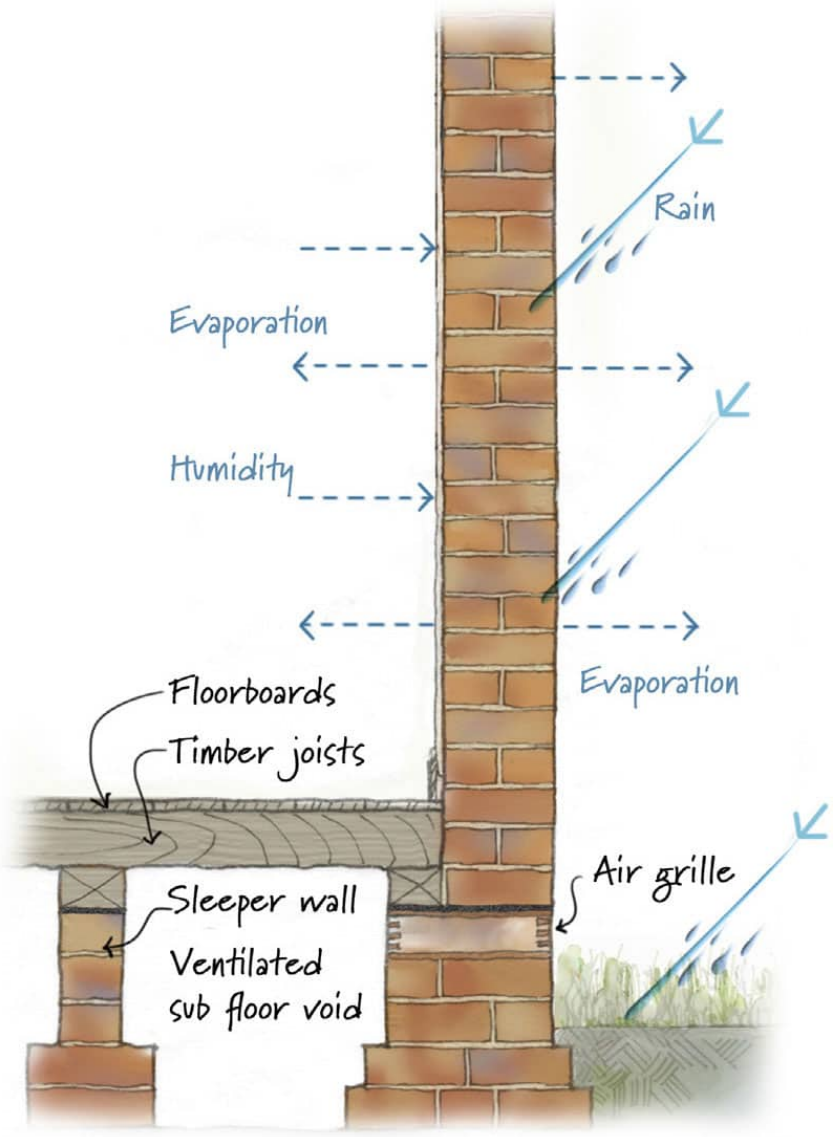
occurs: the new technologies trap water within permeable materials and exacerbate the very problems that they are trying to resolve. Consequently, buildings become damp, unhealthy and thermally inefficient because wet walls provide less insulation than dry ones. Inappropriate alterations are also likely to lead to major works and repairs to the fabric in years to come, resulting in waste, further costs and the use of yet more materials and resources.



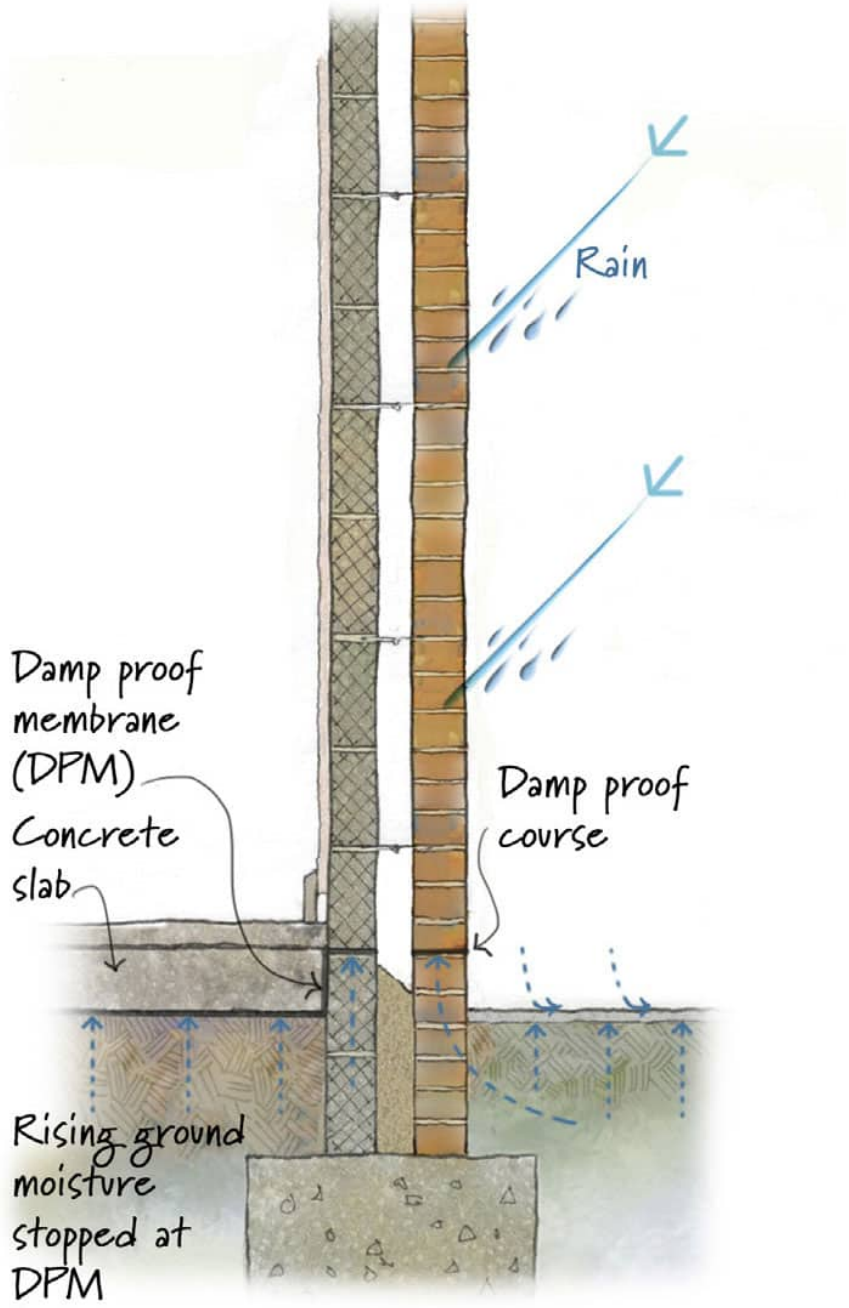
Traditional solid walls were built and plastered in breathable lime-and-clay mixes. They absorbed and released moisture, and readily evaporated rising damp.



Breathing, solid walls are not generally compatible with impermeable modern materials. By applying cement renders, concrete floor slabs and plastic membranes, moisture can become trapped, resulting in dampness, timber decay and a thermally inefficient wall.



From the nineteenth century, brick buildings often incorporated suspended timber floors and slate damp-proof courses but remained breathable, solid-walled structures.



Modern cavity walls work on an entirely different principle from the breathing wall: they are designed to block moisture transfer at every junction and every surface.

LIME

The use of lime products when working with old buildings is essential to their wellbeing. Unlike cement-based materials they produce soft textures, offer useful structural flexibility and, most important of all, are permeable,

so they allow walls to breathe and shed moisture, thus avoiding damp. As lime dries out, it carbonates and absorbs CO_2.

Lime is made from natural materials containing calcium carbonate, such as limestone, chalk or even seashells, burnt in a kiln to form quicklime. There are two basic types of lime: non-hydraulic and hydraulic. Non-hydraulic limes, also known as air limes or fat limes, are produced from materials that are pure calcium carbonate. These offer the greatest breathability and flexibility and are often most suited to older buildings. Non-hydraulic quicklime can be slaked to produce lime putty, but mortars and backing plasters seem to perform better when sand and quicklime are ‘hot mixed’ together with a little water. They can only set when they are exposed to the air – hence the name ‘air limes’ – and absorb carbon dioxide. For this reason, they can be purchased ready mixed as a plaster or mortar.

Natural hydraulic limes (or NHLs) are produced from limestones with naturally occurring impurities, primarily clay. These impurities produce limes that set more quickly and have a higher compressive strength: the greater the quantity of clay impurities, the greater the strength, and they are graded accordingly as NHL 2, NHL 3.5 and NHL 5, with NHL 2 being the weakest and NHL 5 the strongest, or most hydraulic. They are supplied in dry powder form, as they start to set when they come into contact with water. While suitable for some applications, they do not offer the same degree of breathability and flexibility as non-hydraulic limes.

Calcium carbonate, here in the form of limestone, forms the basis of all lime building products.

Using lime

Choosing the right lime products is key, but should not be daunting. Using ready-mixed lime mortars and limewashes makes life easy and lime suppliers are generally happy to offer advice – although, for impartiality on products, you may want to speak to more than one. There are a variety of courses available and it is well worth encouraging your builders to have training, or to get an on-site trainer, if they are unfamiliar with using lime.

As with any material, health and safety issues should be considered. Lime is particularly caustic and can cause damage if splashed in your eyes, so wear goggles and gloves. When dealing with it in powdered form, wear a mask. Having eyewash close at hand is essential and you should always wash your hands after using lime-based materials.

Quicklime is slaked with sand to form a traditional mortar, in a process called hot mixing.

Hydrated lime, or ‘bagged’ lime, is readily available from builders’ merchants and should not be confused with hydraulic lime. It is basically a powdered form of non-hydraulic lime putty, and is sold primarily as a

plasticiser for cement mortars. It is not generally used in old building repair, as its performance characteristics are less assured.

Unsympathetic replacement windows and modern masonry paint have destroyed the character of this Victorian row.

THE NEED FOR CARE

The enduring appeal of old buildings is testament to how they were built and the quality and nature of the materials used. Their layout, the size of rooms and the way they were constructed potentially makes them highly adaptable to modern life. Indeed, single Georgian and Victorian houses are often successfully converted into a number of smaller units to meet changing demand and the trend towards smaller households. This helps make older buildings more sustainable, but remember: in attempting to turn an old building into a modern home, a point may be reached where conservation principles and good practice are compromised to such an extent that the building loses its historic relevance and character. You may be in danger of destroying the very things that originally attracted you to it and made it special.

Vernacular buildings used local materials and traditions and were a response to their particular site.

NATURAL AND SIMPLE

Vernacular architecture grew from its location. For many traditional buildings, materials were gathered locally from the surrounding countryside. This contributed to the distinctiveness of regions and the vernacular styles of towns and villages. By definition most of these materials were natural: timber, clay, stone, thatch. Even when the transportation of goods from one place to another was made easier by the canals and later the railways, the materials used remained predominantly natural in their origins. The difference was that they were mass produced rather than handmade.

Repairability is a key tenet of sustainability; in this case, a door is given new life.

Repairable

The handmade nature of many of the building components used in the past means that they are easily repaired should they fail, so fewer natural resources are used. The most obvious examples are timber windows and doors. It is relatively easy for a good carpenter to cut out a broken or rotten section, such as the bottom rail of a sash window, and insert a replacement part. The same is generally not true with modern products, such as those made of PVCu, where it is frequently necessary to replace the entire unit, even if the damage is fairly minor.

RECYCLABLE AND REUSABLE

From palaces to humble cottages, many buildings have been constructed of material recycled from earlier structures. The beauty of traditional materials is that they can often be reused, sometimes extending the life of buildings by many hundreds of years.

Walling components bonded together with lime mortar and covered with lime renders and plasters are often salvageable. While lime mortar works well when holding bricks or stones together in compression, it is relatively easily cleaned off the surface when a wall is dismantled. Consequently, a brick or stone that has been bonded, rendered or plastered with lime can easily be recycled into a new wall. A brick or stone bonded with cement-based mortar is far less likely to be reused, as it is almost impossible to remove the mortar.

Other traditional building materials such as cob and daub may be reconstituted for use in repairs so there is little or no waste. Timber can be reused for other purposes and, at the end of its life, be burnt for heat. Materials such as thatch are biodegradable, so they are suitable for composting.

Architectural salvage

Reusing materials from known sources is often better than consuming energy and using resources to make new ones, but it is important to verify the provenance of secondhand items to avoid architectural theft or vandalism. Many roofs have been stripped of their tiles simply for monetary gain, leaving the building they protected open to the elements. Ripping out features such as fireplaces can also leave a house devoid of history and character.

While, in some cases, there is good reason to use secondhand materials – perhaps where new pantiles of the same profile are not readily available – reused materials might be nearing the end of their life. For example, clay roof tiles can fail soon after being reused because of inherent frost damage, while salvaged bricks could have been in chimneys where flue gases have reduced their integrity. Similarly, some bricks may be unsuitable for outside walls as they were originally of poor quality and deliberately placed where they were not at risk of exposure to the weather, perhaps in party walls.

In all cases, care should be taken not to confuse the history of a building by introducing materials such as old beams from elsewhere in situations where new equivalents are available. It is often preferable to use new but traditional materials, rather than those that have been salvaged, because maintaining their long-term availability may be more sustainable than the cannibalistic chase of an ever-decreasing supply.

Flooring is commonly resold in architectural salvage yards.

Always check the provenance of items such as fireplaces.

ENERGY PERFORMANCE

Until comparatively recently, little attention was paid to the energy performance of buildings; most were built at a time when the use of fossil fuels and the emission of greenhouse gases was not a concern. Today running costs, energy use and wider environmental issues are prime considerations and a key factor in a building's ongoing sustainability.

This is not to say that old buildings are inefficient when compared with much newer homes. For example, a Victorian or Edwardian terraced house will lose relatively less heat than a detached 1960s bungalow because the external envelope is smaller. Research by the SPAB has also revealed that the walls of old homes often perform significantly better than previously thought in terms of heat loss.

Measuring performance

Setting aside the goals of reducing CO_2 emissions and cutting fuel bills, there is another reason to consider making your house green. In the future, resource-efficient properties are likely to be more highly valued and sought after, while inefficient buildings potentially become less desirable and more difficult to sell or rent.

The energy efficiency of homes can be measured in various ways. The most common when you buy, rent or sell a property are Energy Performance Certificates (EPCs). These are used to show the building's theoretical energy performance in bands similar to those used to indicate the efficiency of domestic appliances. They also estimate carbon emissions and give recommendations for improving energy efficiency. Listed buildings may qualify for an exemption where upgrading would unacceptably alter their character or appearance, so check with your estate agent or solicitor.

Originally introduced as a benchmarking and compliance tool, EPCs are now being used as part of government policies and programmes to drive improvements in the energy performance of buildings. This includes setting minimum ratings for privately rented properties.

Only accredited Domestic Energy Assessors can produce valid EPCs. They visit the building and input data about features such as boilers, heating controls, insulation and windows into a computer program called RdSAP (Reduced Data Standard Assessment Procedure), which provides the calculations for the energy rating. Based on its research, the SPAB argues that this software discriminates inadvertently against traditional buildings built before around 1919.

Worryingly, an energy assessor recommended external wall insulation for this Grade I listed building with elaborate plasterwork known as pargeting.

The energy consumption of the property is modelled on assumptions about the number of people living there, the demand temperature for the heating system and the heating pattern. Consequently, the EPC does not always reflect the actual energy consumption of the property. The recommendations generated regarding energy efficiency improvements are broad, taking no account of specific matters relating to the property such as planning requirements, conservation issues and its structural suitability for certain measures.

There is a danger that the information and recommendations provided by EPCs may result in owners being persuaded, or even forced, to undertake work and efficiency measures that are inappropriate and that could harm the health of the building and its occupants. There are also concerns that, in some cases, the cost of this work may be more than any payback gained from the measures being introduced, and that measures which are harmful to the building may have to be removed and remedial work undertaken in the future.

Embodied energy and carbon

Improving the buildings we live in today often makes a lot more sense than pulling them down and starting again by building new structures. An existing building is potentially more sustainable than one built tomorrow, especially if its energy efficiency can be enhanced through retrofitting.

This has to do with the energy required to erect and operate a building. Energy used for the erection of a building is called embodied energy; that used to run it is called operational energy. Generating energy for these activities often results in emissions of carbon dioxide – for example, when energy is produced by burning fossil fuels, such as coal, gas or oil. Embodied energy has embodied carbon dioxide emissions (embodied carbon) associated with it, while operational energy generates new carbon emissions.

There are no universally accepted definitions of either embodied energy or embodied carbon. The embodied energy relating to the construction of a building includes the energy used in raw material extraction, the manufacture of building products and construction on site, as well as any energy used to transport those materials and products. Embodied carbon is the amount of carbon that has been emitted by these processes.

Rather than being boarded up and threatened with demolition, renovation and retrofit is potentially a more sustainable solution for old buildings.

Retaining an existing building, instead of replacing it with a new one, means that the embodied energy and carbon required to construct a new building are avoided. A new building would need to be much more energy-efficient than the old one; in other words, it would need to have a significantly lower operational energy to overcome the loss of the embodied energy in the old building. It must also be long-lasting in order to recover over time the amount of energy required for, and the amount of carbon emitted from, its erection – its embodied energy.

There is an important distinction between embodied energy and embodied carbon. The amount of embodied energy used for the construction of a house remains the same no matter what source of energy is employed. The quantity of embodied carbon will depend entirely on the means of generating that energy. For example, if a brick is fired using energy generated by wind or hydro power, or it is unfired and baked in the sun, there will be little or no carbon emitted during its production. If the energy generated is from fossil fuels such as coal, gas or oil, however, the level of carbon is likely to be high. Naturally this concept extends to the energy used at all other stages of the process, from the extraction of the raw

materials to transportation to site. For example, timber extracted from woodland using horses has far lower embodied energy and carbon than if mechanical means have been used.

Given all these factors, defining and comparing energy and carbon emissions is far from straightforward. The various methodologies and data used, and the difficulties that result, can produce a wide range of embodied values for any given material or process. In some cases, products are provided with an Environmental Product Declaration (EPD). Although this does not mean that a product meets particular environmental standards, an EPD does provide a standardised way of quantifying its environmental impact, so it can be useful in life cycle assessment.

Orientation

From north-lit artists' studios to nineteenth-century 'butterfly plan' houses, the importance of orientation in buildings has long been understood. In the context of sustainability, orientation is as important as ever, and worth remembering when buying and planning a house, because it is a factor in helping to cut energy costs for lighting and heating.

As with all old houses understanding them through the seasons is vital. Wherever possible, live in your house before making major decisions.

The light and heat from the sun are powerful allies and frustrating foes. They can reduce the energy requirement of a building but may cause overheating and damage fabrics and works of art. Equally, the direction of the prevailing wind and rain might make a difference to the way a house works and the range of problems encountered with dampness and cold.

THERMAL MASS

Many old buildings have good thermal mass. Thermal mass, or thermal capacity in the most general sense, describes the ability of any material to absorb, store and then release heat over time. Heavyweight construction materials such as brick and stone act rather like storage heaters, absorbing and releasing heat, so they can help moderate temperature fluctuations to create a comfortable and largely self-regulating internal living environment.

When used appropriately, the stabilising or buffering effect of thermal mass increases thermal comfort and helps reduce summer overheating, lessening the need for mechanical cooling. Similarly, the ability to store heat can help cut energy use by capturing, and later releasing, solar gains and heat from internal appliances. Thermal mass is particularly useful for buildings in more southerly latitudes where there are large temperature swings between day and night. This is likely to be increasingly important as temperatures become more extreme due to climate change.

Thermal mass is not a substitute for insulation, but the two do have a bearing on one another and can influence decisions as to how and whether to insulate. If insulation is fitted internally, it separates the heated interior from the mass of exterior heavyweight walls, which then no longer provide heat storage. There will still be gains from uninsulated heavy internal walls and solid floors, which will store and release heat.

The disadvantage with thermal mass is that it is comparatively slow to work. Houses with dense masonry walls take much longer and use more energy to heat up than those built with well-insulated lightweight materials.

FIRST STEPS

Before rushing in to make changes, live with your building, ideally through all the seasons. So you have a benchmark, keep an accurate record of your

energy consumption. This process allows you to make better-informed decisions and your ideas will evolve so that you can create a sustainable, comfortable and happy place to live.

02 | OLD HOUSE TO ECO HOUSE

The task of retrofitting any old building to make it more energy-efficient and sustainable needs careful thought right from the start. An approach that considers the whole building is vital, since no single strategy will create an eco house and some may conflict: it is about balancing the particular needs of a traditional structure with the expectations of today.

There is a real danger that ill-thought-through retrofitting of old buildings will destroy the very things that make them sought after, comfortable, healthy and inherently sustainable. Making poor choices now is likely to be damaging to the building and costly and wasteful of resources in the future.

Space heating is almost always the most energy-hungry activity in any home, so retaining heat within the building will invariably have the greatest benefits. This ‘fabric first’ approach often involves measures such as installing appropriate insulation and improving airtightness; this should happen before you look at ways of generating energy. Adopting a long-term, whole-house approach is essential, as it will create the most appropriate and enduring solution.

No two buildings are the same: materials, context, design, orientation and external climatic conditions vary. Detached houses with a large exposed external area benefit most from improved thermal efficiency; smaller attached buildings tend to gain more from the introduction of renewable energy. Consequently, there is no standard formula to suit every house and it can be a tricky balancing act.

With every measure, consider the payback – both in terms of the time it takes to recoup the money spent through reduced energy bills and the carbon saved. It is not always the most obvious, expensive or complicated measures that produce the greatest savings or the most comfortable home.

Above all, think how anything you do may affect the history, character and performance of the building.

FUTURE-PROOFING

Always try to do everything possible to increase the energy efficiency and comfort levels in your house when the opportunity arises. The last thing you want is to have to revisit work you have already done; future upgrades will be difficult, costly, wasteful of resources and likely to cause harm to the building's historic fabric. This is especially true in the case of major renovations or extensions when the work is unlikely to be revisited for many decades. For instance, if you are re-tiling the roof, take the opportunity to insulate it while you have access from above.

Some retrofit measures have a greater visual impact than others.

Terraces like this can easily be spoilt if an individual house is retrofitted unsympathetically.

Give yourself time, carefully research what is available and invest in the fabric of the building. Where funds are limited, look for options that allow more eco-friendly additions in the future. For example, if you are installing a new boiler or hot water cylinder, choose one that will allow a solar thermal system to be fitted at a later date.

This hot water cylinder was chosen with future-proofing in mind. Solar thermal panels can be plumbed to it should they be fitted during re-tiling of the roof at a later stage.

Bear in mind that some new technologies may be superseded relatively quickly, so they should be installed in ways that allow them to be removed with minimum damage to the building. Adding or renewing plumbing and wiring is particularly disruptive so, wherever possible, provide access hatches and try to think ahead so that changes can be made easily in the future. This is especially true in bathroom and kitchen areas, which tend to be refurbished frequently.

PAYBACK

The time it takes to recoup your investment in energy-generation and efficiency measures through the savings you make on your fuel and other bills is known as the ‘payback period’. In theory, this is an easy calculation achieved by dividing the capital cost of the improvement by the estimated annual saving.

In practice, it is not always that simple. The wide range of options available differ greatly in price and effectiveness. Costs and payback periods will vary from house to house and on the exact specification of the measures being proposed. Payback time includes the cost of installation and fees for consultants. In addition, any available grants, subsidies or loans must be considered.

As well as the financial costs, some thought should be given to how much each measure is likely to reduce CO_2 emissions over its life. This is not all: you should also consider the energy payback of a system. For example, how long will a solar panel have to operate to recover the energy used to manufacture it in the first place? Similarly, you should bear in mind the amount of embodied energy and carbon used to source, manufacture and transport the materials and components. It is worth remembering that, in some cases, the warranty on products is shorter than the potential payback time, so replacement may be necessary before payback has been achieved.

Minor work, major benefits

Before embarking on retrofit projects, think about doing simple things that are relatively low cost but often provide worthwhile savings and increased comfort:

- Insulate roof spaces and pipes.
- Draughtproof doors, windows and floorboards.
- Deal with the source of damp problems.
- Carry out regular maintenance.
- Close curtains and shutters just before it gets dark to retain the heat of the day and stop draughts.
- Buy an energy monitor to understand your energy use.
- Review the timings on heating controls.
- Turn down the thermostat by a couple of degrees and overhaul the heating system.
- Heat the rooms you use, not the whole house.
- Replace old lightbulbs with low-energy lamps.
- Install 'A'-rated appliances and turn them off when not in use.
- Dress appropriately – wear warmer clothes!

A smart meter is a first step towards understanding energy usage.

A worrying paradox is that increased energy efficiency tends to lead us to consume more energy. For example, installing low-energy lightbulbs means

there is less incentive to turn them off or that the money saved may be put towards overseas holidays involving flying. This hypothesis has been termed the Khazzoom-Brookes postulate. Our behaviour is therefore a crucial factor in cutting emissions and saving energy; it is vital that all measures introduced are easy to use and that new technology is not so baffling that it is used inefficiently.

Aside from these financial and environmental aspects, it is important to consider the wider benefits that energy-efficiency measures offer in terms of comfort and wellbeing. A home that is hard to heat can be unsustainable because it is uncomfortable and damp.

WHOLE-HOUSE APPROACH

The aim of a retrofit is to make an old house energy-efficient without destroying its integrity or compromising the way it functions. Remember that each thing you do potentially has both a positive and negative impact, and even apparently sensible retrofit measures may result in unintended consequences. For example, if controlled ventilation is not provided, blocking up draughts can lead to condensation. This, in turn, triggers mould growth and potential health problems for the building's occupants, as well as a need for added maintenance.

It can take many years before the cost of replacement double-glazed windows is recouped and visual impact should also be considered.

It is essential to consider the whole house when undertaking a retrofit.

Applying each retrofit measure as part of a whole-house approach that considers the factors which directly affect a building's performance – fabric, services, people and context – helps avoid these issues. The aim is to achieve integration and balance while reaching the best solution with minimum compromise.

To help with this process, the Sustainable Traditional Buildings Alliance (STBA) has created the ‘Responsible Retrofit Guidance Wheel’, an interactive online tool. This is extremely useful when planning retrofit work, as it depicts more than fifty measures that can be used for the retrofitting or refurbishing of traditional buildings. It encourages exploration of the measures’ advantages, concerns about their performance and possible interactions between them.

A thermal imaging camera is a useful way of learning more about your house.

The right time

When considering the installation of technology, remember that it is constantly developing and may, in future, reduce in size and weight. Where such innovations are likely to result in less damage being done to the building, it may be worth deferring the installation of these systems. The same applies to energy-efficiency measures such as internal wall insulation, where its true impact on the fabric of buildings is not yet known.

MAINTENANCE

Maintenance is the single most important thing to consider when caring for any building. It saves wasteful replacement and the use of new materials while resulting in increased thermal efficiency, comfort, cash savings and a reduction in CO_2 emissions. For example:

- Promptly replacing a missing slate or tile saves damage to timber rafters and plaster ceilings due to damp and rot.
- Clearing out or repairing gutters and downpipes means walls stay dry; wet walls are less thermally efficient than dry ones.
- Replacing areas of defective pointing with lime mortar has similar benefits.
- Fixing a broken pane of glass or making sure a window fits snugly keeps heat in and stops draughts.
- Replacing a tap washer prevents water wastage and saves the use of chemicals to remove water stains from sanitary ware.

BE PROPERLY INFORMED

Buildings are often unwittingly damaged through lack of knowledge. Understanding your home, its materials, structure, history and surroundings should be a priority and often proves to be much of the fun of ownership. Books and magazines are useful resources and the web is invaluable, although there is potential for misinformation, confusion and conflicting opinions, so do your research thoroughly. ‘Green’ and ‘eco’ are words readily bandied around so it is important not to be misled by greenwash and unfounded claims, particularly about the breathability of products. Always try to seek out impartial advice and be wary of those offering help who have something to sell.

Steps to a whole-house approach

There are three steps towards making a house more energy efficient and sustainable. These should always be based on a whole-house approach, with a master plan or 'road map' that focuses on how all the various measures will ultimately work effectively together.

- Quick wins: simple and easily reversible DIY measures that are achievable, affordable, cause the minimum disruption and potentially offer significant immediate gains. These include draughtproofing, fitting low-energy lightbulbs, installing loft insulation and overhauling the heating system.
- Exploiting opportunities: there are numerous examples of upgrades that can be undertaken when other work is done. If a new boiler is required, choose a model with the best possible energy performance. Where windows need repair or replacement, look at the options for draughtproofing and secondary glazing.
- Major renovation: this allows significant opportunities for everything from wall and floor insulation to energy generation measures.

Concentrate on the quick wins such as loft insulation, in this case using sheep's wool, before considering more invasive measures.

Lack of maintenance and benign neglect accelerates decay in old houses.

With old buildings it is not always possible to know the extent of the undertaking until you begin. When opening up, even the simplest job can reveal an unexpected defect that is costly to repair and will set back the programme. The work may also be considerably more expensive because of the need to source and use traditional materials and craftspeople, so never underestimate the cost of completing the project. Work out what you can afford and, if you go ahead, prioritise the work. Always allow a contingency in terms of both time and cost.

PLANNING THE INTERIOR

Good interior design is about more than just using sustainable products and materials; it also takes account of emotions and influences wellbeing. It embraces everything from light, colour, materials and textures to layout, ergonomics and acoustics. The way tactile elements and spaces are brought together, the flow of the rooms, the orientation of the building and the

introduction of sunlight all contribute to energy efficiency and sustainability.

SPAB advice

The SPAB provides advice over the telephone as well as details of specialist suppliers, craftspeople and building professionals. It runs courses and events to provide homeowners and those employed to work on old buildings with the knowledge necessary to make informed decisions about their repair. The Society also has a range of publications, including 'The SPAB Approach to the conservation & care of old buildings', which are highly respected for giving authoritative and practical guidance.

When thinking about a building's interior, bear in mind that living spaces generally have higher requirements for daylight. Natural daylight is beneficial to health and minimises the need for artificial light, so should be maximised for work areas such as kitchens and home offices. Bathrooms and bedrooms need far less natural light, so are best located on a building's north side. Similarly, natural ventilation results in less dependence on mechanical ventilation.

Durability is essential to sustainable design. If items are inherently fragile, poorly made or difficult to maintain, they will be quickly replaced at further environmental cost.

Interior design must make sustainable behaviour within a household easy. For example, designated places for drying clothes and storing recyclable waste are useful, while energy monitors displayed in a prominent position help you appreciate energy use.

Barn conversions require the relevant consents for change of use.

Practical measures such as fitting doors in corridors and circulation spaces will reduce air movement in draughty interiors, although they must be designed so they can be left open during warmer months to aid ventilation. Similarly, fitting a curtain at the bottom of a staircase can help cut draughts caused by warm air rising.

RULES AND REGULATIONS

There are three main types of consent that may apply to proposed works: building regulations approval, planning permission and listed building consent. Contact your local planning authority and building control department for advice.

A listed building is usually protected in its entirety, inside and out, regardless of the listing grade, and structures within its ‘curtilage’ (the land around it) can be covered in the listing too. Most listed buildings fall into the ‘hard to treat’ category when it comes to energy-efficiency measures. Not only are their walls generally framed or solid (as opposed to cavity), but their fabric is particularly sensitive, their aesthetics precious and their history important.

Building Regulations

The guidance to the Building Regulations is divided into Parts, each relating to different aspects of construction, and is designed to ensure that people are safe in and around buildings.

Part L, ‘Conservation of Fuel and Power’, comprises four documents relating to energy efficiency. This refers to ‘thermal elements’ of the building: the walls, floors, ceilings and roofs that make up the ‘thermal envelope’. An attached garage or a conservatory is considered to be outside the thermal envelope, provided it is not heated and is separated from the main building.

Owners of existing houses will be concerned with Part L1B, ‘Existing Dwellings’, which covers alterations and extensions. This also refers to ‘controlled services’, such as space heating, hot-water systems and fixed lighting, and ‘controlled fittings’ such as windows, rooflights and doors.

Building regulations are not set retrospectively, so existing houses are not affected by the requirements of, or changes to, the regulations, unless and until work is being carried out. General repair and maintenance will usually not require building control input, provided it does not make matters worse in terms of energy efficiency, but always check with your building control officer if unsure.

New extensions to old buildings must comply with the regulations and guidance set out for new dwellings. The standards are, however, reduced for ‘retained thermal elements’ such as existing walls, floors and roofs. L1B states that, where the thermal performance of the element is worse than the threshold value set out in the regulations, it is acceptable to improve only to the lower standard.

A lower standard may also be accepted if:

- Internal wall insulation would lead to a reduction in floor space of 5 per cent or more.
- Floor insulation would cause a trip hazard due to steps.
- The benefit, in terms of payback over fifteen years, is not achieved.

In simplified terms, existing buildings will need to be thermally upgraded when:

- They are subject to a ‘material change of use’, such as when a shop or barn is converted into a house.
- There is a change in the building’s ‘energy status’, where a building not previously subject to energy-efficiency requirements is converted into one where they do apply.
- Previously unheated/uninhabited spaces are converted. For example, where a garage or loft is converted into a habitable room.
- More than 50 per cent of any thermal element is being changed or renovated. For example, more than half the wall is being re-rendered or clad, or more than half the roof covering is being stripped and re-tiled. In this instance, the whole of that thermal element would need to meet the standards.
- More than 25 per cent of the total building envelope is being changed or renovated. In this instance, the whole building envelope would need to be improved.
- The U-value for an existing thermal element does not meet a defined ‘threshold’ value (See U-values, shown here).

There is a conditional exemption for listed buildings, buildings within conservation areas and scheduled monuments. These do not have to comply if this would unacceptably alter their character or appearance internally or externally. This means that the sash windows of a building in this category, if beyond repair and requiring replacement, could be replaced as single-glazed sashes. In addition, the Building Regulations have three extra categories that benefit from ‘special considerations’:

- Locally listed buildings.
- Buildings of architectural and historic interest such as those within national parks.
- Buildings of traditional construction with permeable fabric that both absorbs and readily allows the evaporation of moisture (See Building regulations, shown here).

The explanation of the Building Regulations above refers to the 2010 regulations for England and Wales and is by no means comprehensive. Due to the complexities involved, it is always recommended that the local building control officer is contacted to discuss the details of a project.

Extensions must meet current building regulations.

This Grade II listed 1840s house underwent an extensive but sensitive retrofit, meeting the AECB Building Standard and reducing space heating demand by more than 75 per cent.

TOP TIP: KEEP IT SIMPLE

The more complex a system becomes, the more opportunity there is for failure. Old buildings have lasted for hundreds of years because of their simple construction and

repairability. Try to adopt the same philosophy when retrofitting by keeping the methods, systems, materials and detailing as simple as possible.

STANDARDS

Being able to measure what you propose doing against known benchmarks is useful when undertaking a retrofit, and working to a known standard offers a level of predictability about the outcome.

The Passivhaus Standard, developed by the Passivhaus Institute in Germany, is the best-known energy-efficiency fabric standard. Buildings built to the standard are designed to provide good levels of occupant comfort while using very little energy for heating and cooling. Unfortunately, achieving the exacting level of efficiency required when retrofitting is difficult within the constraints of a building's existing fabric. With this in mind, the Passivhaus Institute developed EnerPHit, a 'quality-approved energy retrofit with passive house components'. The standard provides for 'an economically and ecologically optimal energy retrofit, for old buildings that cannot achieve passive house standard with reasonable effort'.

Try to use local, sustainable materials wherever possible.

Look for evidence of certification when selecting materials, such as the PEFC label on this pack of timber.

This is not the only standard. The AECB Building Standard is aimed at those ‘wishing to create high-performance buildings using widely available technology at little or no extra cost’. It estimates that this low-risk option will reduce overall CO_2 emissions by 70 per cent compared to the UK average for buildings of each type.

CHOOSING MATERIALS

The sustainability of materials and products relates to their environmental impact over their lifecycle, from cradle to grave. Always try to use natural,

local materials. Look for those gathered from sustainable sources that use less energy, preserve and protect the building, and can be recycled, reused or composted once the building has reached the end of its life.

Materials that might initially appear to have a high environmental impact, such as granites and marbles, are not necessarily ruled out: things of beauty and value tend to get passed on as part of the building rather than being ripped out and dumped in landfill.

In the case of timber, forest certification schemes provide a way of defining sustainable forest management as well as third-party, independent verification that a timber source meets the definition of sustainability. The two most commonly encountered certification schemes in the UK are the Programme for the Endorsement of Forest Certification (PEFC) and the Forest Stewardship Council (FSC).

The suitability of crop-based products, such as straw for thatch and timber for many forms of structural and aesthetic purposes, is well proven over centuries. Many products bring environmental benefits in use, such as better air quality, natural management of moisture levels and reductions in allergic reactions. Crop-based materials have the potential to offer advantages relating to the environmental impact of both the production and eventual disposal of the products they comprise. These benefits are typically due to the low embodied energy of the material, reduced pollution and ease of disposal through composting.

The choices we make about our homes have a direct effect on our wellbeing.

HEALTH AND WELLBEING

Human health is directly affected by the built environment, both physically and psychologically. Children and the elderly are the most vulnerable. The young may be exposed to conditions within buildings, such as poor air quality, that result in illnesses which have an impact throughout their lives. Older people increasingly feel temperature asymmetries and draughts as they become less mobile.

‘Sick building syndrome’ is a recognised condition and may be attributed to such things as internal temperatures, light levels and, most commonly, dampness and air quality. Symptoms can include headaches, nausea, fatigue, and skin, eye, nose and throat irritation. Studies have shown that the indoor environment – where most of us spend around 90 per cent of our time – can be up to ten times more polluted than the external environment. This is particularly worrying when we are seeking increased airtightness in buildings. Adding inappropriate thermal insulation and improving airtightness potentially causes or exacerbates the problem, as dampness and mould growth may occur. Pollutants, such as secondhand smoke from cigarettes and off-gassing from volatile organic compounds, as well as

odours, are also less able to dissipate and CO_2 concentrations are likely to rise.

Radon is a further issue. Radon tests, monitoring equipment and alarms are available and should be used to determine the problem before, during and following work to improve airtightness. Where radon barriers to floors are considered necessary they may have an impact on the structure (See Breathable floors and radon, shown here).

Contamination

Many old buildings contain materials that are potentially damaging to health, notably lead and asbestos. Lead-based paints perform well and, until the 1960s, were commonly used, particularly on timber and metalwork, but concerns over their toxicity led to their use being banned except in certain circumstances (See Dealing with old lead paint, shown here). Lead water pipes are also common and you may wish to have your drinking water tested for lead content.

Asbestos was used widely in all types of buildings because of its fire resistance and thermal properties, until its harmful effects were fully realised in the mid-1980s. Asbestos may be found in boilers, heaters, pipework and materials, including some textured wall finishes, roofing, floor tiles, adhesives, wall linings and doors. Asbestos fibres and dust are dangerous if inhaled. If you are unsure whether or not asbestos is present, leave well alone and consult a competent asbestos surveyor or a contractor with the proper training and equipment to deal with it.

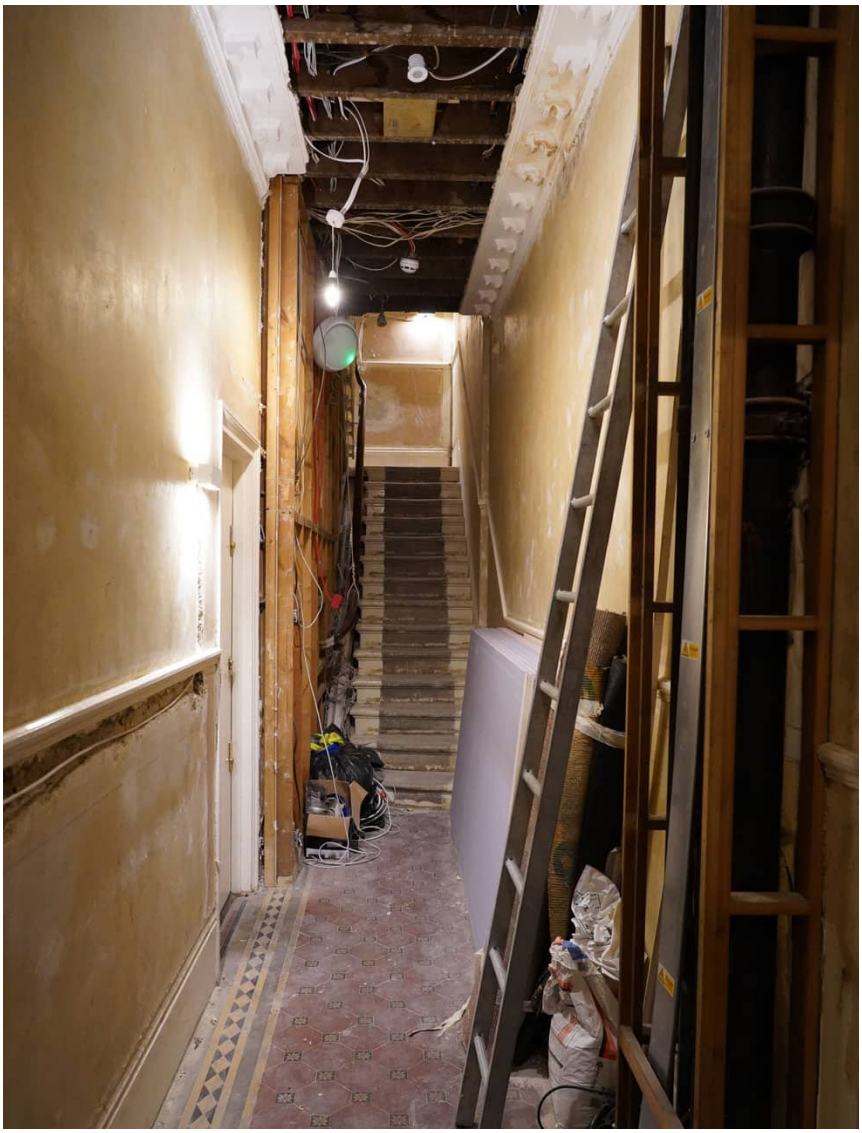
Some buildings, especially those associated with industry, may have other sources of potential contamination, such as redundant oil tanks, or may stand on or near land contaminated by chemicals or materials relating to past use. Care needs to be taken to ensure that these cannot leach into water courses and cause damage to local eco systems. They may need to be dealt with by specialist contractors.

Acoustics

Refurbishment can affect the transmission of sound, which causes stress and affects wellbeing; this is especially problematic in apartment buildings

and flats. Clearly it is not possible to acoustically insulate all old buildings without destroying their special values, but insulation between floors and on walls can help. Some insulating materials are better at absorbing sound than others. For example, tongue-and-groove wood fibreboards are particularly effective, whereas closed-cell foam boards are poor. It is also worth remembering that lime plaster creates better and less echoey acoustics than gypsum.

Lead piping is common in old houses. This lead waste pipe is not a risk, but water supply pipes should be replaced.



In houses converted into flats, thought must be given to the acoustic insulation of elements such as stud walls, floors, ceilings and service risers.

Sound insulation between dwellings is tricky, and expert advice from an appropriately qualified person is advisable, although there are some simple points to bear in mind:

- Taking up carpets and leaving floorboards bare, or laying hard floor coverings, will create problems in rooms beneath and may change the acoustics of the room itself.
- The holes cut for recessed downlighters in ceilings provide a path for noise between floors.

- Gaps around windows let in noise. This is particularly relevant if you are on a road or beneath a flight path.
- Chimneys often allow the transmission of sound from one part of a building to another.
- Ventilation systems can be noisy and allow sound transmission through ductwork.
- Placing power sockets or light switches back to back may allow the passage of sound.

GETTING THE WORK DONE

Although many building professionals and contractors are hugely knowledgeable about old buildings, others are less so and often do not grasp the range of issues that must be considered, particularly when undertaking retrofits. There is no easy way of finding the right person or company for your project, but researching old buildings, materials and building techniques will help you understand the subject better and make it easier to distinguish those who are suitable from those who are not.

Contractors

Old buildings have always required careful craft skills and attention to detail, but making them energy-efficient is potentially even more demanding. Tasks such as installing insulation and achieving airtightness demand diligence and understanding if they are to be successful, and unnecessary damage to the building's fabric is to be avoided.

Take care to brief contractors and to nurture a good working relationship. As with professional advisers, look for builders with a good track record and don't be afraid to ask for references. Consider whether they have sufficient experience of both old buildings and retrofitting to a standard high enough to achieve the levels of performance you are seeking. Wherever possible, get quotations from at least three contractors on a like-for-like basis, based on a proper schedule and specification prepared by a professional or consultant, unless the work is very minor. Never pay a contractor upfront, always in arrears. It is wise to get the work checked as it progresses by an independent specialist.

Good communication between client, consultant and contractor is essential.

When the project starts, allow time to be on site to check that work is being properly executed and is of the quality you expect. Discuss details with your contractor, and make sure they are filtering through to those actually doing the job. Alternatively, an architect, building surveyor or project manager can do this for you. Bear in mind that, however good the reputation of the firm, the quality of the finished project is reliant on individuals and they may be subcontractors.

Retrofits often consist of various layers being correctly applied. Try to see new work or materials at each stage, particularly the fitting of insulation as, once covered, it is very difficult to establish whether it has been installed to specification. Remember that jobs such as clearing roof spaces and fitting new insulation can be dirty and unpleasant. If you are appreciative of the person carrying out the work, you are likely to get a better job.

Waste and recycling

Inevitably, building work creates waste from stripping out or demolishing existing structures. The use of new materials results in offcuts and surpluses as well as a wide range of packaging materials including cardboard boxes, timber pallets, metal banding, plastic shrink wrap, cans and bottles.

This waste is expensive to get rid of, contributes to landfill and leads to further depletion of natural resources. The SPAB philosophy of repair rather than replacement helps cut waste, but it is still worth looking at further ways to reduce, reuse and recycle (See Architectural salvage, shown here.

MONITORING

Understanding how a building is performing is a vital part of the retrofit process. Monitoring may be required before work starts and into the future, and can be particularly necessary where problems associated with moisture have occurred in the past.

Monitoring can reveal potential problems. Here data is being collected to better understand how a secondary glazed window is performing.

Renovating and retrofitting old buildings may involve stripping out large quantities of inappropriate materials such as concrete.

Monitoring may be a simple matter of checking a loft space or examining walls for condensation or damp spots on a regular basis. Sometimes it is advisable to include access hatches in floors or panelling where insulation has been added to allow checks to be made for moisture-related problems or even insect or rodent infestation.

In certain situations more sophisticated monitoring and data collection is used, both to identify potential problems and to judge the long-term performance of the retrofit. These systems rely on sensors being placed in rooms, within the fabric of the building or externally. Various devices may monitor such things as temperature, humidity, wood moisture content, air quality, rainfall, wind speed and direction, solar radiation and energy and water use.

Some sensors have a battery life in excess of fifteen years, so can be buried in the structure – such as in timber joist ends – during the retrofit process. Operating wirelessly, information is then uploaded to the internet, enabling the data to be accessed and analysed online. Certain systems are capable of providing email alerts should problems occur – for example, when moisture is detected as a result of a pipe or gutter leaking into the building's fabric.

Waste checklist

Think about how waste can be reduced:

- Choose materials that will be more easily recycled or reused in the future.
- Design new work with a view to minimising waste. For example, use standard-sized components so that unusable offcuts will be avoided.
- Try to buy materials on the understanding that any surplus can be returned.
- Oblige builders and sub-contractors to cooperate in waste minimisation as part of their contract.
- Think about ways of recycling or reusing materials.
- Wherever appropriate, recycle waste concrete and brick by using it as hardcore or in soakaways.
- Segregate waste on site to make recycling easier.
- Try to keep as much waste on site as possible to save unnecessary transport and landfill. For example, accommodate soil dug from footings in garden landscaping.
- Keep spares. For example, surplus floor tiles can be stored under a kitchen unit's plinth to allow you to repair, rather than have to replace, the floor if it suffers damage.

03 | THE BUILDING ENVELOPE

Ensuring that the building envelope – the walls, floors, roofs, windows and doors – is as thermally efficient as possible is important, but any alterations should be carefully considered. This ‘fabric first’ approach can have unintended consequences, particularly if it reduces the building’s natural ability to breathe.

Solid-walled buildings work because water vapour within their structure can escape unhindered, resulting in a state of moisture equilibrium. With careful maintenance and the use of appropriate materials, old buildings will last hundreds of years without major damp problems – but this balance can easily be upset.

Retrofitting to increase a building’s thermal efficiency must be undertaken with great care. Poorly considered insulation materials and techniques may lead to moisture becoming trapped, resulting in mould and decay that are damaging to the building’s fabric and the health of the occupants.

Every building is different, so there is no ‘one size fits all’ retrofit solution. Preconceptions are dangerous and the installation of certain products is potentially disastrous. The biggest problems may occur when materials designed for use with modern construction systems are used in old buildings; many of these act as a barrier to moisture and do not take account of the need for traditional structures to breathe.

Even neighbouring houses may have subtle differences that could affect choices made about retrofitting.

The walls, roofs and windows of a house form part of the building envelope, so should be as thermally efficient as possible.

Spreader plates in old walls act as thermal bridges. These can become problematic if walls are insulated.

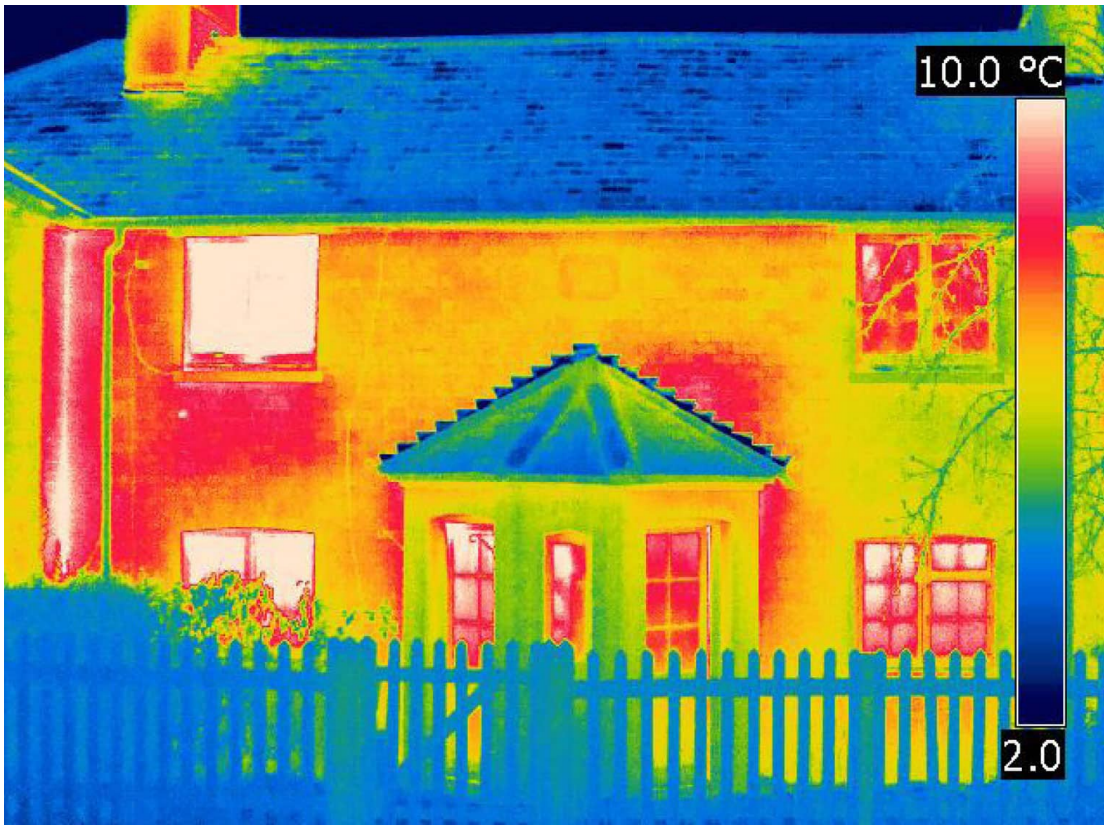
The pressure to make thermal improvements is huge and the advice offered can be contradictory and confusing. It is important to be well informed to recognise inappropriate products and unscrupulous salespeople. Understanding a little of the science will help you arrive at the right decision.

HOW OLD BUILDINGS LOSE HEAT

The external envelope of a building loses heat in two very different ways, the most noticeable being through air leakage – gaps around windows and

doors, cracks in walls, and junctions between different building elements that allow warm air to escape and draughts (cold air) to penetrate. Heat is also lost via conduction through the building fabric itself, passing through walls, roofs, floors and even panes of glass.

Heat loss through air leakage is much faster than heat loss via conduction, so airtightness is more crucial than insulation. Insulation on its own will not necessarily provide airtightness.



Thermal imaging is an ideal way of analysing areas of heat loss.

Thermal conduction and resistivity

Heat passes through different building materials at different rates. Metal is a good thermal conductor, wood is not – which is why we use a wooden spoon rather than a metal spoon to stir the contents of a hot pan. Brick and stone fall somewhere in between and are moderately good thermal conductors. Consequently, the amount of heat lost through traditional walls depends on their thickness, density, moisture content and construction.

Thermal resistivity is the opposite of thermal conductivity and is sometimes used to illustrate the insulation value of a material. For example, insulating quilt has low thermal conductivity and high thermal resistivity. Generally, the thermal properties of a material are related to their density. Denser, heavier materials are able to conduct heat, whereas lightweight materials contain a high proportion of air and therefore resist the flow of heat.

Thermal bridging

When insulation is added to existing buildings, any weak points in the insulation layer will form concentrated areas of heat loss known as thermal bridges. Where these occur, not only do they cause heat loss but they also attract condensation. Whereas the uninsulated building spreads the condensation over large areas, in an insulated building any condensation will be focused at thermal bridges where the surface is relatively colder.

Examples of elements that provide thermal bridges include metal-framed windows, concrete floor slabs, steel lintels and metal fixings. For instance, screws penetrating insulation materials will allow heat to bypass the insulation and act as a thermal bridge.

Air leakage

Sometimes referred to as air permeability, air leakage is the uncontrolled movement of air (draughts) through joints and gaps in a building’s fabric and can be a significant source of heat loss.

When old houses are draughty, this tends to be due to open flues, ill-fitting doors and windows and cracks in the structure. Some of these areas of air leakage are easy to resolve through sensitive repair, but the quest for airtightness often results in loss of historic features and inappropriate alterations.

Windows are notorious for air leakage, but issues such as rot must be properly dealt with and the source of the problem identified, rather than employing quick fixes.

Air leakage is driven by a pressure difference between the internal and external environments, either sucking in or pushing out air. The pressure difference is caused by three main factors:

- External wind around the building envelope, inducing positive and negative pressure.
- Warm air inside the building rising due to the ‘stack effect’.
- Mechanical ventilation, drawing air out of the building.

Wherever air is lost from a building or rises as a result of heating, it causes fresh air to be sucked in from outside in the form of draughts. The effect is most noticeable on cold, windy days when the pressure differential between inside and outside is at its peak and the air being sucked in is much colder than the air that is lost. Most freezing days are accompanied by still air, so heat loss via draughts is less evident than on a mild but windy day.

Extra energy is required to heat cold air from draughts, making a leaky house inefficient compared to a house that is airtight.

The terms ‘air leakage’ and ‘air permeability’ should not be confused with breathability and vapour permeability. The latter terms do not relate to air movement through a building’s fabric, but the movement of water vapour; they are linked to the pore size and structure within the fabric itself. A building can be airtight and still be breathable.

The quantity of smoke coming out of a chimney gives a clear indication of the amount of air being pulled into and through a house via draughts and other means.

Likewise, airtightness and insulation are two different things. A building may be airtight and have no gaps or cracks but, if the building envelope is poorly insulated, heat will be lost through the fabric due to conduction. Conversely, insulating a draughty building is going to produce limited results if measures are not first taken to reduce air leakage.

Decrement delay

Decrement delay refers to the time taken for heat generated by the sun (solar gain) to pass through the building envelope. This is particularly relevant to attic rooms that suffer from excessive overheating during the summer months. It is related to a more common scientific term, ‘thermal diffusivity’, which measures the rate of transfer of heat through a material from the hot side to the cold side.

Whereas thermal insulation and U-values (See U-values, shown here) deal with steady state conditions (in other words, relatively constant internal temperatures), decrement delay responds to dynamic, fluctuating temperatures such as those emitted by the sun over the course of a day. Generally, materials that have the longest decrement delay and perform best are those with a combination of high-density, low thermal conductivity and high specific heat capacity – or the ability to store heat relative to their mass.

The black slate covering the roof of this house will make the upper rooms particularly vulnerable to solar gain. The problem can be dramatically reduced by choosing insulation materials that have good decrement delay.

For this reason, a foam board insulation at rafter level may be excellent at stopping heat flow from leaving a heated attic room in the winter, but it will perform badly when protecting that same room from overheating due to solar gain on a hot summer's day. Cellulose-based insulation materials have particularly good decrement delay, and wood fibre sarking boards, coupled with wood fibre insulation batts, perform exceptionally well.

Ideally, an insulated roof should have a decrement delay of between 10 and 12 hours. This means that, when the sun is at its hottest at midday, the heat will not pass through to the room inside until night time when the temperature has dropped. By then, an open window will let in cool air and any stored heat can be partially released and re-radiated to the outside.

MEASURING HEAT LOSS

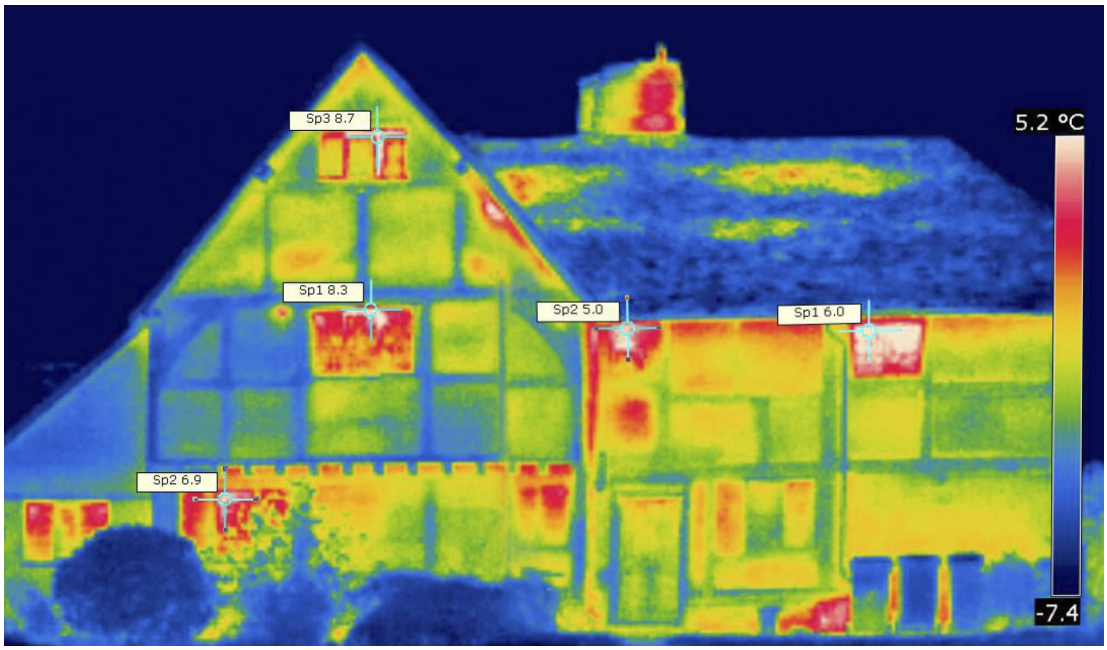
Heat loss due to conduction, as well as key areas of air leakage, may be analysed using a thermal imaging camera. Air leakage is measured with an airtightness test. Importantly, both techniques are non-invasive to the building.

Thermal imaging

Infrared thermography, or thermal imaging, is used to detect the infrared radiation that is emitted by all objects: the warmer the object, the more infrared radiation it emits. Thermal imaging cameras detect this radiation, with its varying levels translated into a range of colours that correspond to the relative temperatures of the objects being viewed. This means that heat loss in the form of uninsulated areas, as well as air leakage, can be seen. Materials that have decayed, voids within the structure and moisture-saturated areas may also be detected.

Thermal imaging works best when a building is heated internally and the external temperature is cold, otherwise all surfaces may appear similar. Ideally, 'thermograms' should be interpreted by experts and must generally be read in conjunction with visual surveys and other investigations of the structure. Without sufficient experience, the images can be confusing because of the need to consider the effects of the sun, shadows, moisture, details within the building's fabric and the varying levels of thermal radiation given off by different surfaces.

This thermal image of the timber-framed house above shows variations in heat loss across its facade. The white patches indicate areas of greatest heat loss, invariably through air leakage. Note the white spot under the gable verge, and draughts around the edges of windows. Red and then yellow are the next most thermally inefficient areas. Just above the front door, a red patch shows a radiator losing heat through the wall and the yellow patches to the roof indicate missing areas of insulation. The large inglenook chimney is losing considerable heat through its stack and the eaves are also poorly insulated.



TOP TIP: SIMPLE AIRTIGHTNESS TESTING

While airtightness testing is a useful way of analysing the level of draught, it is possible to carry out a DIY version. Simply wait for a really windy day, and run your hand along any suspicious areas, such as around window and door frames, cracks and recessed spotlights. You should be able to detect draughts on your skin. Another indicator is the presence of spider's webs. These are often located in draughty spots in order to catch flies.

Airtightness test

This is sometimes referred to as a 'blower door' test. The testing procedure involves sealing extractors, wall vents and chimneys, as well as trickle vents and flues. An external door is then opened and a temporary airtight screen with a fan is fitted into the frame. This is generally used to depressurise or suck air out of the building, to create a pressure difference between the inside and outside of approximately 50 pascals (Pa). The airflow through the fan and the pressure differences are then measured and the airtightness of the external envelope can be assessed. The test normally takes around an hour; during this time, the house can be occupied as normal.

For new buildings, airtightness must meet the requirements of building regulations. For old buildings, the test provides a useful tool to analyse the level of draughts.

The assessment will give a measurement of air leakage but, even more usefully, while the fan is running, it is possible to pinpoint draughts that may not have been previously apparent. When the building is depressurised, it creates a lower internal pressure that sucks air in from outside through any gaps in the building fabric. If you run a smoke pen, or even the back of your hand, around junctions and penetrations, draughts can be identified. It may be worth using a pencil to mark any points of air leakage so that they can be remedied in due course.

The level of airtightness is measured in $m^3/(h.m^2)$ at 50 Pa. In other words, the quantity of air (in m^3) that leaks out of the building per hour divided by the total surface area in m^2 of the building, including party walls, at 50 Pa

of pressure difference. The lower the value achieved, the more airtight the dwelling.

Above and Below: An airtightness test in progress.

A smoke pen, emitting non-toxic smoke, can indicate air leakage while the fan is running.

MEASUREMENT TERMS EXPLAINED

A number of standard units of measurement for expressing insulation and heat loss properties are used:

Lambda (λ) values and k-values: Confusingly, these two values both represent the thermal conductivity of a given material and are identical in meaning. While engineers tend to use k-values, building products are more frequently expressed as lambda values. Every material has its own value and these can be used to compare the insulation properties of one product with another; the lower the value, the more insulation it provides. For example, the value of sheep's wool insulation is typically 0.037, fired brick is on average 0.47, and iron is 80. The lower figure for sheep's wool immediately shows that it is a much better insulator than brick; the high figure for iron indicates that it is a good thermal conductor, with virtually no insulation value. In the UK, k-values and lambda values are given in W/mK (watts per metre kelvin).

U-values: Thermal transmissivity, or U-values, define the rate of heat transfer through a building component – for instance, a wall, floor or roof for a specified thickness. They are the standard way of expressing heat loss via thermal conduction. For any given construction, the U-value is calculated using the lambda value of each layer and its thickness. U-values are expressed in W/m²K (watts per square metre kelvin). The lower the U-value, the better the thermal efficiency of the building component. The higher the U-value, the more heat is lost and the less energy-efficient your home will be.

For example, the U-value of a traditional 9 inch (225 mm) solid brick wall is around 2.1 W/m²K. This is calculated using an average lambda value for brick of 0.47, divided by the wall thickness, 0.225 m. Using the same lambda value, a 131/2 inch (338 mm) solid brick wall has a U-value of 1.4 – the slightly thicker wall loses heat at a reduced rate. Whereas the U-value will vary according to the thickness of the wall, the lambda value for a particular type of brick will remain constant. To determine the U-value of a series of different layers (for instance, in an insulated wall), the calculation becomes more complex.

R-values: The opposite, or reciprocal, of U-values, R-values express thermal resistivity for a material of a given thickness – in other words, the ability of the material to resist heat flow. In the case of insulating materials, a high R-value indicates a better insulator than a low R-value. Thermal resistivity is measured in m²K/W.

A timber-framed house with 4 inch (102 mm) thick brick panels has a high U-value, with walls that are thermally inefficient. The thatched roof, with a low U-value, performs well.

SAP and RdSAP: Standard Assessment Procedure (SAP) is the UK government's methodology for assessing and comparing the energy and environmental performance of new dwellings. Reduced Data SAP (RdSAP) was introduced in 2005 as a simpler, lower-cost method developed for existing dwellings. A range of calculations and measurements are used to determine a final rating. SAP ratings are expressed on a scale of 1 to 100+. The higher the number, the better the rating; over 100 means the dwelling is a net producer of energy when considering heating/hot water and lighting.

This limewashed rubble stone wall, with internal lime plaster and external lime pointing, benefits from all three breathable processes.

UNDERSTANDING BREATHABILITY

The way materials interact with moisture is complex and the materials you choose will have a major impact on the way your building fabric functions. It is crucial to understand some of the basics before making decisions about how to repair and insulate an old house.

Breathability is a widely used but rarely defined term. In its strictest sense, breathability is the water vapour transmission rate, or the speed at which vapour passes through a particular material or construction. In a practical application, breathability is a combination of three important processes:

1. Water vapour diffusion
2. Liquid water diffusion (capillary transport)
3. Moisture buffering (hygroscopicity)

It is not necessary for all three processes to operate for a structure or material to be breathable, but making use of them all, in the correct configuration, often produces the greatest breathability.

1. Water vapour diffusion

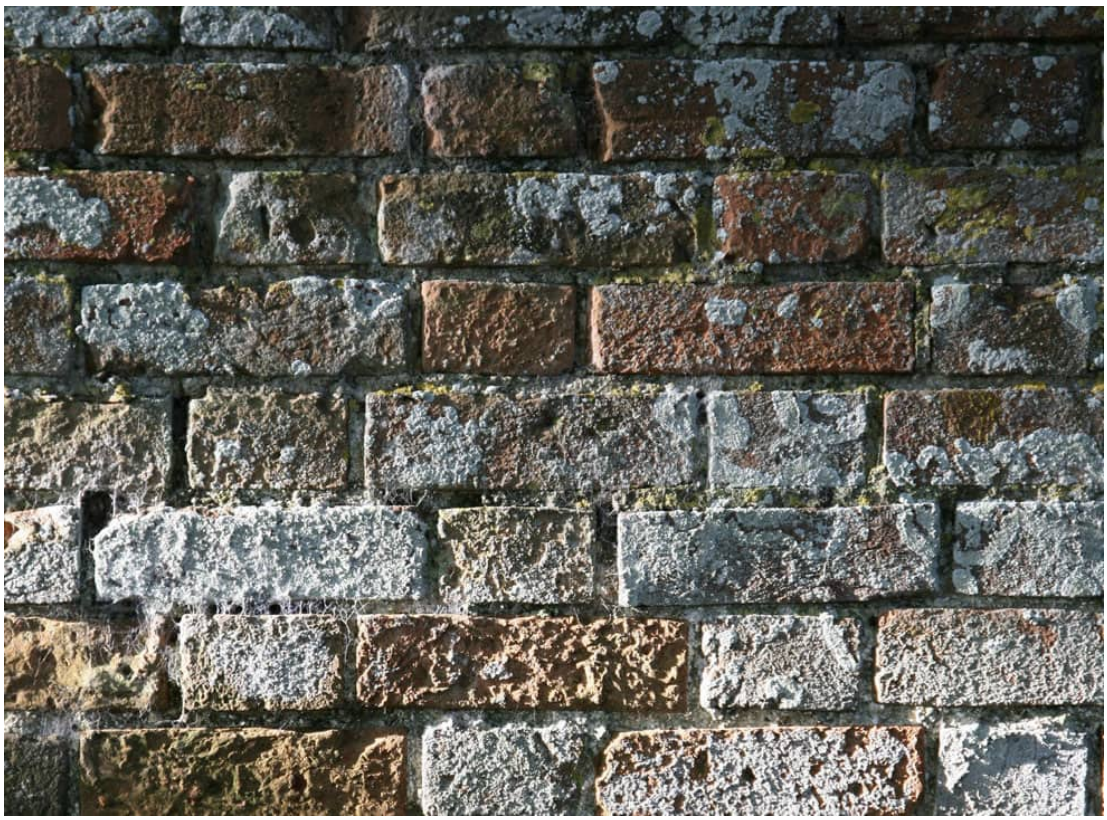
The way in which water vapour travels through a vapour-permeable material is described as vapour diffusion. When there is a larger concentration of water vapour on one side of a vapour-permeable material, it will diffuse to the other side containing the lower concentration, because of the vapour pressure difference. A good example of this can be seen if you lay a piece of paper over a cup of boiling water. The vapour is visible passing through the paper and rising up. The internal environment of a house usually has a higher vapour pressure than the external, and vapour travels from the inside to the outside. For this reason, a breathable structure is designed with increasingly permeable layers towards the outside face, encouraging vapour to diffuse to the external environment.

Porosity and vapour permeability: These describe two very different properties of materials that are frequently confused. Porosity relates to the percentage of pores – also referred to as cells, capillaries or voids – within a material. Vapour permeability is the rate of passage of water vapour through a material, via the pores. Permeability is largely dependent on whether the pores or cells are open, linking one to another, or whether they are closed. A material can be highly porous, but completely impermeable – for instance, a sheet of closed-cell foam insulation. The closed cells (pores) will trap a great quantity of air, making them very good thermal insulators, but they will be a barrier to water vapour transmission and therefore not generally breathable.

2. Liquid water diffusion (capillary transport)

Liquid water diffusion, also known as capillary transport, capillary action or wicking, is the process by which liquid water is drawn into a permeable material through interlinking, open pores or cells. When a porous brick is left in a few millimetres of water it will quickly ‘wick’ or suck up the moisture, due to capillary transport. The amount of moisture it sucks up will depend on the capillarity of the brick – the pore size and shape, and the way the pores are connected. This is how rising damp occurs in walls when they are saturated at the base and have no physical damp-proof course. A course of a low-capillary material, such as a slate or dense engineering brick, or non-capillary active materials, typically a plastic membrane, provides a

capillary break to resist rising damp. As retrofits, these are unlikely to be suitable additions to a traditionally constructed building.



Old bricks are highly porous and, because the pores are linked, vapour permeable.

The capillarity of a material can be tested by placing it in water to see how much is wicked up.

Materials with high capillarity are described as capillary open or open cell. These can be easily identified, as they darken when they get wet; for instance spots of rain on a limewashed wall are immediately visible, indicating that the surface is storing liquid water.

Vapour open, capillary closed treatments and finishes:

Some external treatments and finishes have been developed to be vapour open but capillary closed. In theory, this is a means of allowing any water vapour within the fabric to evaporate to the outside while preventing liquid water, in the form of rain, from passing through to the internal surfaces. It is achieved by treating a capillary-open surface with a water-based paste or liquid that lines the pores (making them repellent to water), but does not block the pores, thus still allowing the free passage of vapour. These are generically known as hydrophobising agents.

Such treatments are sometimes recommended in particularly exposed locations where driving rain is an issue, or where walls are constructed of brick or stone with high capillarity. It is generally a non-reversible treatment and should be carefully considered before application. Multiple treatments may reduce vapour permeability. It also has the effect of preventing the wall from absorbing rain across the whole surface, causing water instead to run down the wall and concentrate at the base. Because of this, any cracks or defects towards the bottom of the wall are exposed to higher quantities of run-off and are more vulnerable to water penetration.

Injected DPCs – why they should be avoided

Injected damp-proof courses are marketed as a way of retrospectively fitting a capillary break into the base of a wall suffering from rising damp. The technique requires a series of holes to be drilled into the lime mortar joints, and a silicone-based fluid is injected under pressure. As the lime mortar is more capillary open than the brick, the fluid theoretically travels sideways along the joint to form a continuous, horizontal, impermeable barrier to rising moisture. In reality, this rarely works and is usually unnecessary, expensive and damaging. Installers almost always drill into the brick rather than the lime mortar, but this can never work as rising moisture travels around the brick via the mortar joints. Holes are usually drilled at a downward angle and are rarely plugged, leaving a perfect pathway for rainwater to travel into the wall and exacerbate the damp problem. Invariably, the treatment is only guaranteed if combined with a waterproof cement tanking plaster on the inside face of the wall; this traps moisture and masks the problem, leaving the wall damp, cold and therefore thermally inefficient.

Low-level dampness in solid-walled, breathing structures can usually be resolved by addressing the cause of the damp, allowing the wall to dry out and then repairing it with vapour-permeable, capillary-open, lime-based mortars and plasters.

This retrospective damp-proof course has been injected into the bricks, but will almost certainly have no effect. It is an irreversible scar on the building, and may even exacerbate the problem.

Clay plasters and breathable paints play a useful role in moisture buffering.

3. Moisture buffering (hygroscopicity)

Moisture buffering, sometimes referred to as hygroscopicity, is the ability of a material to store and release water vapour. Such materials will readily absorb excess vapour as the relative humidity (RH) in the room increases and will release vapour as it falls. The process buffers and helps regulate any fluctuations in RH, helping create a more stable environment.

An example of this is the small paper sachet filled with hygroscopic silica gel found inside a new suitcase. This is designed to hold excess water vapour when the suitcase is stored in a cold warehouse and prevent mould from forming inside.

Activities such as showering, cooking and drying clothes, or simply breathing and perspiring, all increase the RH within a house. In a draughty building, this will be managed to a large extent through natural ventilation but, as we make buildings more airtight, the moisture-buffering abilities of the materials we use become more important. Many natural products such as woodfibre-based insulation, natural quilts and clay plasters will help to stabilise RH and reduce the risk of condensation and mould growth.

Relative humidity: Relative humidity is the amount of water vapour in the air relative to the maximum amount that could be held in the air at that temperature. Air at a higher temperature can hold more water vapour, hence a warm room is less likely to feel damp than a cold room. Ideally, RH should be between 40 and 60 per cent for good internal air quality. Once RH is above this, dust mites and mould can thrive and pose a serious threat to human health. Not turning on heating to save money can be a false economy: the colder the internal temperature, the less able the air is to hold water vapour and RH will rise. Consequently, soft furnishings may smell musty and go mouldy.

Condensation is particularly noticeable on single-glazed windows in bedrooms and bathrooms where the relative humidity is high. This also encourages black mould to grow on the frame.

Indoor air quality and ventilation

While airtightness is critical to make a building thermally efficient, ventilation remains equally important to control RH levels and ensure good indoor air quality (IAQ). It plays a crucial role in reducing RH by swapping internal moisture-laden air for drier air from outside. This is particularly important during and after activities such as cooking and showering, when RH can reach 100 per cent.

Ventilation should be controlled, rather than being allowed to occur randomly due to air leakage and draughts, although this is not always possible to achieve in an old house to the same degree as a new one, where airtightness is built in during construction.

At least 0.4 air changes per hour (ACH) are recommended in modern homes. This equates to 40 per cent of the total volume of air within the building being replaced every hour. With old buildings, adequate ventilation should be provided to ensure that any excess moisture in the air does not cause damage to the building's fabric. If a building is particularly damp, additional ventilation may be required to reduce moisture levels.

Control might be by passive means, including simply opening a window at regular intervals, or through mechanical ventilation. A ventilation rate of between 0.5 and 1.5 ACH for the whole dwelling will usually be sufficient to control condensation, but each building must be considered on a case-by-case basis.

Medium-level air quality is defined as having between 400–600 parts per million (ppm) of CO_2. We cannot perceive IAQ easily ourselves, but internal CO_2 concentrations above 600 ppm may lead to stuffiness and levels above 1000 ppm can cause drowsiness.

MEASUREMENTS OF BREATHABILITY

There are several different measures of breathability quoted by manufacturers, which can make it confusing to compare one material with another.

Moisture vapour transmission rate (MVTR): This quantifies the amount of water vapour (in grams) able to pass through a metre square surface area over a 24-hour period. The higher the figure, the more water vapour can pass through and, therefore, the more breathable the material. A typical clay paint has a figure of 1115 g/m_2/24h, compared with a standard vinyl emulsion paint, which measures 400–500 g/m_2/24h.

Sd (steam diffusion) value: This compares the breathability of a given thickness of a material – usually paint – to the equivalent air thickness layer

measured in metres. For a paint to be classified as breathable, it is generally accepted that it should have an Sd value of between 0.01 and 0.5. A paint with an Sd value of 0.5 means that a single layer of paint has the equivalent vapour permeability of a 0.5 m thick layer of air.

Vapour resistance: As an alternative to an Sd value, breathability can be measured by looking at the vapour resistance of a specified thickness of material. This is the inverse, or opposite, of the MVTR, and a low figure indicates a more breathable, or vapour-permeable material. Vapour resistance is measured in meganewton seconds per gram (MNs/g) and a material of up to 2.5 MNs/g is defined as having high levels of breathability. For example, a 19 mm thick non-hydraulic lime render has a low vapour resistance of approximately 1 MNs/g and, as such, has excellent breathability credentials.

Mu-value (μ): Water vapour resistance can be expressed as a factor, referred to as the mu-value. This compares the resistance of a given material to the passage of water vapour, to the resistance of still air. This can be used to directly compare the breathability of different materials, regardless of their thickness. For example, still air has a mu-value of 1, non-hydraulic lime plaster measures 7.3, and polyurethane foam has a mu-value of 100, meaning it is 100 times more resistant to the passage of water vapour than still air.

Unventilated cupboards on external walls are particularly prone to condensation and mould due to the combination of cold surfaces and stagnant, humid air.

The sustainability of old buildings is dependent on making properly informed decisions.

CONDENSATION AND DEWPOINT

Condensation occurs when water vapour in the air makes contact with a cold surface and condenses, returning to a liquid. The temperature at which it condenses is called the dewpoint. This is often noticeable on cold external walls, uninsulated ceilings and poorly ventilated corners of rooms behind cupboards where air circulation is minimal. Condensation also forms on areas where thermal bridging is present. The higher the relative humidity, the more moisture is present in the air and the more likely condensation is to occur.

Condensation can lead to the formation of mould growth on surfaces. Aspergillus niger is particularly common and is readily identified by a patch of small black spots. This mould prefers pure condensed water, hence it is a good indicator of condensation rather than any other form of damp. Rising and penetrating damp usually carry salts from either the building fabric or the ground, so do not provide appropriate conditions for this type of mould.

Interstitial condensation

Water is the biggest enemy of old buildings in the UK and keeping the rain out has long been a preoccupation. But water in the form of vapour, passing from the internal environment and condensing within the wall, remains invisible and is therefore regularly overlooked.

During the colder months, there is a big temperature difference between the internal and external wall surface. Somewhere in between, within the body of the wall itself, the temperature is at dewpoint and, when vapour hits dewpoint, it will condense. This is known as interstitial condensation – that is, condensation forming part way through a material or component, rather than on the surface.

Analysis

The risk of interstitial condensation has traditionally been calculated using Glaser diagrams. These were developed in the 1950s to analyse the experimental techniques of lightweight construction that were appearing at the time. Glaser diagrams are relatively easy to use: they have two inputs, the thermal conductivity of each material and its vapour permeability. They assume that the wall is always kept dry and protected from rain. This is not always the case with old buildings, as breathing walls allow moisture – both

as vapour and as liquid (rain) – to move through the structure; consequently, moisture levels are constantly changing due to varying use patterns and weather. The Glaser diagram is not able to consider all the complex factors involved in a breathing wall (and indeed in any wall), such as the capillarity and moisture-buffering qualities of materials, driving rain and solar drying.

A far more accurate condensation risk analysis can be carried out by using a dynamic hygrothermal simulation that takes into account all the properties of the building fabric and the conditions to which they are subjected over a period of time. Such simulations should conform to EN 15026 – for example, WUFI (Wärme Und Feuchte Instationär) or Delphin software. These models consider a whole range of factors in a dynamic state and produce far more accurate modelling, but are limited by the material data for traditional buildings. This tends to underestimate the thermal performance of materials such as cob, rubble stone and wattle-and-daub, which SPAB research has shown to perform better than predicted in the majority of cases (See How do walls compare?, shown here).

Many manufacturers and specifiers continue to use the over-simplistic Glaser analysis. This can lead to misleading results and potentially inappropriate choices, particularly for older buildings.

Timber decay

Old buildings invariably contain embedded timbers such as joist ends, bonding timbers and lintels. Provided the building is well maintained and these elements remain relatively dry, few problems are likely to occur. For a safe working figure, a maximum timber moisture content of around 12 per cent is often quoted.

When buildings are retrofitted, particularly where internal wall insulation is added, the moisture content of embedded timbers can increase if the detailing has not been properly considered. This can make them vulnerable to dry rot and beetle infestation.

For many years there has been a common misconception that chemicals can eradicate timber decay and beetle infestation. Yet practical experience and scientific studies have indicated that the best way to overcome such outbreaks is simply to dry out the timber and reduce the moisture content to within safe limits. Despite overwhelming evidence to support this advice, a chemical timber treatment industry has grown up offering questionable ‘solutions’ and guarantees, often insisted upon by mortgage providers.

Chemicals are rarely necessary or effective against timber decay. Furthermore, blanket spraying without good justification is contrary to the Control of Substances Hazardous to Health Regulations. In fact, spiders are the best natural predator of beetles, yet they are killed by chemicals. If necessary, while timber is drying out, a localised treatment with borax may help control outbreaks of beetles; this is a naturally occurring mineral with preservative and insect-repellent properties.

Beetle attack potentially results in serious damage to timber.

04 | RETROFIT MATERIALS

Adding thermal insulation to the building envelope helps reduce heat loss via conduction and makes your home more thermally efficient and comfortable but, on its own, it may not necessarily provide a total solution. Other materials, including breathable membranes and tapes, may be needed to address issues such as airtightness and to complete the retrofit process.

The palette of materials available to improve the overall performance of buildings has increased significantly, making it ever more important to choose carefully. There is always a risk of creating problems if inappropriate materials are selected, detailing is poor or installation is badly executed. With this in mind, it is essential to ask the question: ‘If I insulate, draughtproof or carry out other measures, am I going to change the way the building works and potentially cause its fabric to fail or affect the indoor air quality?’.

Many retrofit insulation and membrane solutions are part of a system. Conversely, old buildings are generally relatively simple in their construction, with the walls, roofs and floors formed of just a few layers of highly compatible materials. Endeavouring to make these buildings thermally efficient can result in an inherently complex, multilayered approach involving a diversity of materials. This may work well, but the aim should always be for the simplest possible solution. The goal should be to achieve a building that is wind- and watertight, thermally efficient and comfortable, without compromising its breathability or the integrity of its historic fabric.

Both internal and external systems are used, sometimes in combination. In all cases it is vital to think through the build-up and fixing of materials carefully before starting. To ensure the required performance is achieved, time must be costed into the job at the very beginning. This should account

for the proper detailing and specification of insulation, membranes and other associated products, as well as for their correct and meticulous installation.

MOISTURE AND MATERIALS

Damp problems in old buildings are often exacerbated by attempts to keep moisture out by using inappropriate cement renders, plastic membranes and concrete floor slabs. Adding modern, impermeable insulation to the building envelope is likely to trap moisture and have the same disastrous consequences. This means it is essential to understand how traditional solid-walled buildings work, and to ensure that any intervention is compatible. Although there are many so-called breathable products, they often have little ability to diffuse water vapour so they are entirely incompatible with traditional fabric. The type of insulation and membranes used, coupled with the way they are installed, is key to the health of both the building and its occupants.

Flexible wood fibre batts are one of the natural insulation materials available.

Vernacular buildings reflect the materials found in their surroundings. Some of these materials, including timber, aggregates and sheep's wool, are now being used to create insulation products.

One of the considerations when choosing insulation materials is ease of cutting and fitting.

Breathability of building products

If a manufacturer or supplier makes claims regarding the breathability of a particular product, it is reasonable to request that they provide details to validate this. As a minimum, this could be supplied in the form of an MNs/g measure of vapour resistance (See Measurements of breathability, shown here). This value is relatively easy for the manufacturer to obtain, either via materials testing or through conversion from other measures of vapour permeability. In the case of multi-layered materials, only the vapour resistance of all layers together, including adhesives, can give an accurate indication of its breathability. In the absence of this basic information, you

may wish to consider whether the use of the particular material or system in question is prudent in an older building.

INSULATION MATERIALS

Selecting materials carefully and understanding how they work within the overall retrofit is essential and will often require a bespoke approach. It is not unusual for a large and varied palette of insulation materials to be employed in a single building in order to achieve the highest thermal standards and the most appropriate solutions. The choices made will take into account the material's compatibility with localised areas of the building's fabric based on their relative thermal performance, acoustic properties, ease of use, embodied carbon and cost.

Genuinely breathable materials minimise the risk of trapped moisture, while those with additional moisture-buffering properties also assist in managing relative humidity (RH) by absorbing and releasing water vapour. Some materials are thin and highly insulating, and so they are ideal where space is limited; others are cheaper but require a greater thickness to achieve the equivalent level of insulation. The relative performance of materials is readily assessed by comparing the lambda value of each, although actual performance may vary depending on individual manufacturers' products (See Measurement terms explained, shown here). Most manufacturers provide product overviews to make selection easier and allow direct comparisons. Where a technical advice line is provided, it is worth discussing concerns or queries directly – but do remember that such advice is not necessarily impartial.

Finding space to store retrofit materials on site is an important consideration.

TOP TIP: CUTTING INSULATION MATERIALS

When materials need to be cut to size, check with the manufacturer how this should be done. Generally, it's better to cut roll, batt and quilt materials with a saw or a sharp knife – with a plain or serrated edge – than to tear them apart, but bear in mind that blades tend to blunt quickly. Cutting quilt insulation is often made easier by first compressing the material with a straight edge.

Over time, some insulation materials will slump and their performance will decrease. Many materials perform poorly if wet. In all cases, any damp problems within the building must be resolved and, generally, the building's fabric allowed to dry out before insulation products are installed. Where insulation materials become saturated with water, they will often need to be removed and replaced.

To perform effectively and to avoid problems such as thermal bridging, attention to detail is everything. All insulation materials must be carefully installed in accordance with the manufacturer's instructions, while taking into account localised issues and general good practice.

Material forms

Insulation materials come in a variety of thicknesses, sizes and forms, so it is important to compare like with like when considering performance and cost.

Quilts or rolls provide long lengths and flexibility, but can suffer from sag and are easily compressed, resulting in air pockets and unintentional heat loss.

Batts or slabs are firm or semi-rigid forms that come in manageable lengths and offer some flexibility. The advantage of batts is that they can be cut slightly wider than needed to provide a compression fit between rafters and studwork without buckling and with no need for mechanical fixing.

Boards are rigid materials, sometimes of large dimensions, that require accurate cutting to size to avoid gaps around the edges. Consideration needs to be given to any access constraints when using large boards (for example, loft hatches) and the ease of cutting if space is limited.

Loose-fill and blown insulation materials are either pumped in by professional installers or poured. By their nature, these products fill every nook and cranny, even around pipework and wiring, but the disadvantage is that the material can find its way out through gaps, so plugging these or putting barriers in place prior to the insulation being installed is vital. Some materials may settle over time, which can result in voids. In draughty loft spaces, there is the potential for certain loose-fill products to be displaced by air movement.

Aggregates and granules are often poured as stand-alone insulation solutions, but some are mixed with lime products to create insulating renders and plasters.

Spray foams expand on application through a chemical reaction. Their use is limited in old buildings.

The flexibility and firmness offered by insulation materials is an important consideration. Some materials are better than others at creating a tight fit and accommodating uneven surfaces; this helps to reduce the danger of

voids forming between the insulation and the substrate. All forms of insulation must be cut accurately to the dimensions required. Squashing the material will compromise its effectiveness, as it can only perform to its designed U-value at full thickness. Leaving gaps around the edge leads to thermal bridging and, sometimes, air leakage. In most cases, and especially with quilts, batts, loose-fill and blown products, insulation materials should be used in conjunction with a windtight but breathable membrane.

Acoustic insulation

Insulation materials can perform an important role in reducing noise transmission and creating quieter spaces. Heavier and denser insulation materials, such as wood fibre insulation, can be particularly good at this, but sometimes a balance has to be struck between a product that provides the levels of thermal insulation required and the desired acoustic performance.

Material flammability

All insulation products should meet regulations governing building materials and, where necessary, be treated with fire retardants. When selecting materials, consider not just the combustibility of the material but also flame spread, how long the material will continue to burn after the source of ignition is taken away and the harmful smoke and noxious gases that may be given off while burning. Some leave behind toxic ash residues.

Insulation materials are only as effective as the amount of air trapped inside. They will not achieve their full insulating potential if they are squashed.

Stone mineral wool is one insulation material that has extreme resilience to fire.

Health and safety

When using insulation materials, always follow the manufacturer's recommendations, as some products can cause severe irritation to the skin, eyes and respiratory tract. Depending on the product, face masks, gloves and other personal protective equipment (PPE) may be necessary. Natural insulation materials are generally pleasant to handle, although it's advisable to wear a face mask in enclosed spaces such as lofts, especially where dust and previously installed insulation and other potentially hazardous materials may be present. When selecting a mask, choose a respirator type that has replaceable filters, rather than a disposable paper mask.

Old insulation, as with other building products used in the past, can contain asbestos, particularly pipe lagging and certain loose-fill and sprayed coatings (See Contamination, shown here).

Worryingly, many of those involved in installing insulation materials do not wear the recommended PPE. Tasks such as fitting insulation are often seen as unskilled, so are given to low-paid workers. With the long-term effects of some materials not yet known, it is vital that products are specified responsibly and that appropriate PPE is worn.

Insulation checklist

There are a number of key points to consider when selecting insulation. These will depend on your priorities and where the material is to be used:

- Does it need to be breathable?
- Should it offer the potential to buffer moisture?
- Must it resist prolonged exposure to moisture – for example, at the base of walls or below ground?
- Will it provide the thermal performance required?
- Does it need to help manage summer overheating – for example, in attic rooms?
- Will it be compatible with thermal bridging, airtightness and ventilation strategies?
- Is the durability or compressive strength of the insulation important?
- Does it provide a satisfactory fire rating?
- Is acoustic insulation required?
- How practical and easy is it to use?
- Can it be cut and fixed appropriately?
- Is there sufficient space for it to be stored and installed?
- Are you keen to use natural products?

- Is the cost affordable and justified?
- Is it likely to off-gas and affect indoor air quality?
- What is its embodied energy and carbon?
- Is the material non toxic and biodegradable at the end of its life?
- Is it robust enough? For example, does it need to be impact resistant?

Vital questions for suppliers

When using insulation materials and systems in situations where the building's fabric needs to breathe, it is vital to do research before buying. Ask potential suppliers or the manufacturer's technical adviser the following questions:

- Do they have experience in advising on old buildings and breathable structures?
- Are they able to carry out a condensation risk analysis?
- Is the condensation risk analysis based on Glaser or a hygrothermal simulation such as WUFI? (See Analysis, shown here). Avoid any analysis based on Glaser, as it is unlikely to provide accurate modelling of an old building.
- Are they able to supply a detailed written specification?
- Is it tried and tested and can they provide case studies of similar applications?
- If it is advertised as a breathable product, what does this mean – has the breathability of the product been quantified?

Builders often fail to wear PPE when installing products, potentially putting themselves at risk.

Hemp shiv – the chopped up, woody core of the hemp plant – is mixed with lime to create hempcrete, a breathable insulation and construction product that is ideal for use in old buildings.

Hempcrete is sometimes used to replace lost timber frame infill panels.

Open- and closed-cell products

Closed-cell insulation products such as foam boards contain lots of separate gas-filled pockets that slow down the movement of heat through the material. As the cells are not interlinked, they are not vapour permeable and are a barrier to moisture.

Open-cell products have interlinking cells/pores and are therefore able to diffuse liquid water and water vapour. Most natural insulation materials come under this category. Some synthetic open-cell products are not moisture buffering, so lack synergy with historic breathable fabric as they are unable to wick away, diffuse or temporarily store moisture (See Understanding breathability, shown here). Generally, the thermal performance of open-cell insulation is not as good as that of closed-cell products, and a thicker layer of the material will be required to achieve an equivalent value. Open-cell products are, in most cases, much better at dampening the transmission of sound.

Natural materials

Produced from renewable materials, the composition of natural insulation products generally gives them useful attributes that are often less readily available with synthetic products. This generally makes them the first choice for use in old buildings. Natural materials usually allow the building's fabric to breathe and their good moisture-buffering properties assist in managing changes in RH. Some offer effective acoustic insulation. Most are biodegradable or recyclable at the end of their life, do not off-gas and are safe to install with minimal protective clothing. They may include binders and many have additives, such as naturally occurring mineral salts, to provide fire resistance and fungal, insect and rodent protection. Plant-based natural fibres have the added benefit of sequestering CO_2.

Cellulose insulation is a loose-fill insulation produced from recycled paper. The material may be blown into loft spaces, timber studwork and closed panels.

Cork bark harvested from the cork oak is highly sustainable, as the bark grows back without damage to the tree. Used internally and externally, it is available as boards, loose fill and in a granular form that may be used as an aggregate to create insulating lime plasters and renders. Cork is dimensionally stable and resistant to compression.

Hemp requires few or no pesticides to grow, replenishing the soil with nutrients and nitrogen, and erosion of the topsoil is controlled. Offering good moisture-buffering properties, hemp is available as batts.

Hemp/lime mix (hempcrete) is a composite material used in monolithic form made from hemp shiv and a lime-based binder; it may be precast, cast in situ or sprayed. It takes 12 months to reach optimum thermal performance due to its drying time and creates a very stable internal thermal and moisture-buffering environment. As it is a quasi-construction material, rather than purely an insulant, its performance cannot be directly compared with that of other insulation materials.

Jute is a flexible fibrous batt insulation that contains no nutrient base for rodent and insect life. It has thermal storage capacity and offers good moisture-buffering properties while acting as an effective noise-dampening material.

Recycled cotton fibre, made using unwanted garments, particularly old jeans, is available in rolls, batts and loose fill and offers good moisture-buffering, thermal and acoustic properties.

Sheep's wool is available in roll and batt form to suit different applications; some products are combined with recycled polyester. It has natural fire resistance, and modern sheep's wool products are treated against insect attack, although, as a precaution, it is sometimes not used in areas that are inaccessible and where monitoring is not possible.

Wood chip (mineral coated) is sold as a loose fill for stud walls or aggregate that is either blown or poured to provide thermal and acoustic insulation. The mineral coating prevents the chips from being affected by moisture, pests, mould or fungal attack. These products can also be used as a load-bearing insulant for floors.

Cellulose.

Cork.

Hemp.

Hemp/lime mix (hempcrete).

Jute.

Recycled cotton fibre.

Sheep’s wool.

Wood chip (mineral coated).

Wood fibre insulation is made with waste softwood and is breathable, vapour permeable and moisture buffering. Blown, flexible batt and board products are available.

Wood fibreboard materials are produced either by a wet or a dry process. To manufacture wet-processed boards, wood pulp is mixed with water and then heated, releasing the wood's natural lignin and glues. The resulting boards are ideal for internal use, as they are good at transporting moisture away from the building's fabric. Dry-processed boards are produced using a synthetic resin as a binder; this reduces the board's capillarity. Both wet- and dry-processed boards may be used externally.

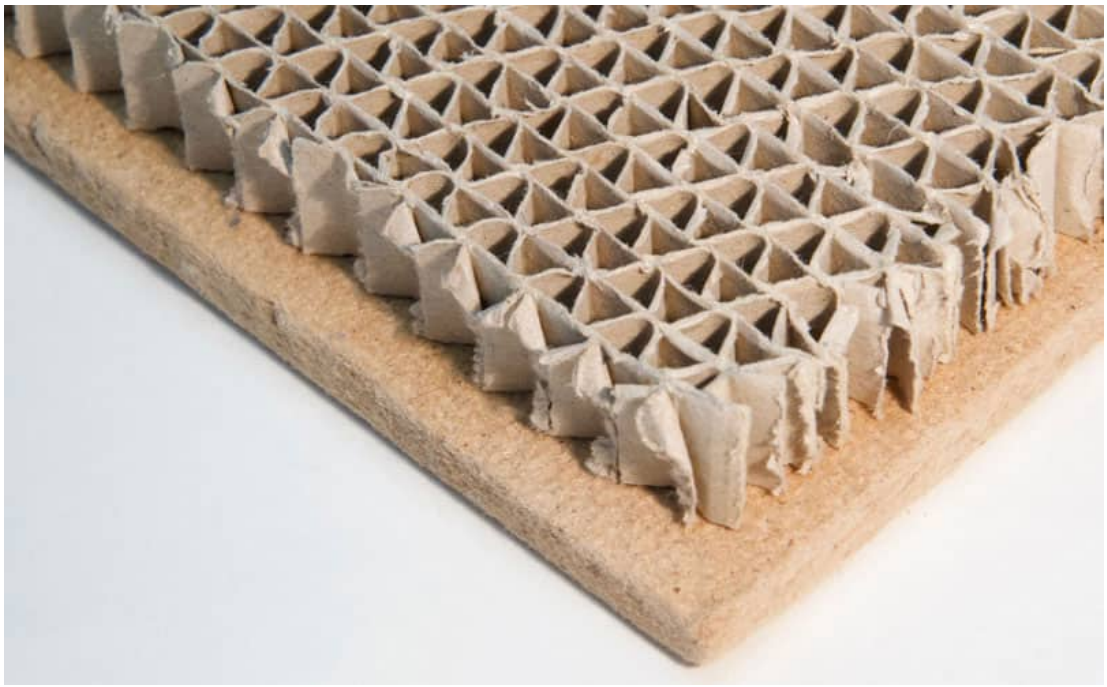
Wood fibreboards are available in a variety of thicknesses, tailored to specific purposes, with some impregnated or coated to enhance moisture resistance and durability. Certain boards have a built-in vapour control layer to help prevent the build-up of interstitial condensation. Wood fibre sarking boards are designed to be exposed to the weather for a period of time during roof work. These, and some other types of wood fibreboard, are tongued-and-grooved so that they interlock, helping to achieve a higher degree of airtightness and good acoustic insulation.

Blown wood fibre.

Flexible wood fibre batts.

Wood fibreboard.

Airtightness and acoustic insulation are improved with tongued-and-grooved wood fibreboards.



Where space is limited or extra acoustic insulation is required, ultra-thin wood fibreboards are available that are combined with a honeycomb matrix on the rear side, which traps air between the wall and the board.

Mineral materials

Although mineral-based insulation products are based on naturally occurring materials, the extraction and production processes involved can be damaging to the environment. In some cases, a high proportion of recycled material is used and it is worth checking the percentage, as this can vary depending on the manufacturer.

Some products offer vapour diffusion and liquid water diffusion, but are not necessarily moisture buffering; not all are biodegradable or recyclable.

Aerogel has a thermal conductivity of 0.015 W/mK, so it is one of the world's most effective insulation materials. It combines silica gel with a fibre matrix to create an extremely thin blanket, making it an option for use where space is at a premium but performance is critical. The material is vapour permeable, repels moisture and is hydrophobic. It can be supplied laminated to a variety of board products.

Aerogel.

Calcium silicate is manufactured by combining lime, silica and reinforcing fibres in an autoclave under heat and steam pressure. The board material is moisture buffering and highly capillary active. It does not rot and the high PH and molecular structure of the board mean that mould growth is inhibited. These qualities make calcium silicate useful for vulnerable walls such as single-leaf masonry, in basements and areas where natural fibre insulation products would be unsuitable.

Calcium silicate.

Foam glass aggregate (FGA) is manufactured from recycled glass fired at around 800°C and mixed with a foaming agent, which creates bubbles within the softened glass that trap air. This gives it excellent insulation properties. It is cast in sheets, then crushed to create large and angular granules, with various size ranges available. FGA is a closed-cell product that does not absorb water. Once laid, the air voids around each granule provide a capillary break to prevent rising ground moisture, without the need for a damp-proof membrane. The product's angular particle shape means that the individual pieces lock together, so it is easy to walk on and has a high compressive strength.

Foam glass aggregate (FGA).

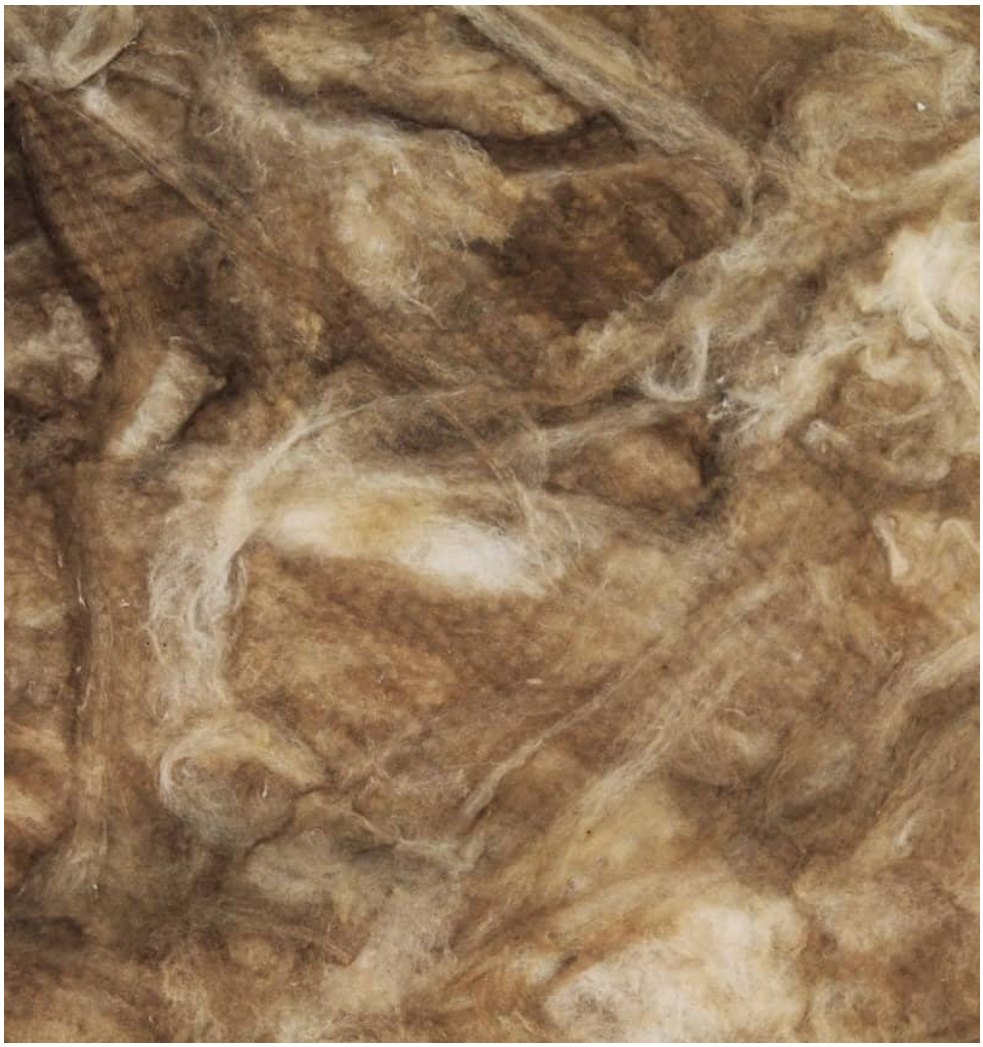
Aerogel blanket (top of picture) can be used on its own but is available bonded to an airtightness membrane, or to materials such as plasterboard, plasterboard and plywood, or magnesium oxide board, to increase its versatility.

Foam glass beads/bubbles provide a versatile and lightweight insulating system that can be used with or without a lime binder. They are highly insulating and closed cell, as described above. Unlike FGA, the free-flowing beads can be easily poured to fill voids, but their spherical form prevents them from locking together to provide compressive strength.

Foam glass blocks/slabs/boards have a high compressive strength and can be used where it is necessary to eliminate structural thermal bridging.

Foam glass beads/bubbles.

Foam glass blocks/slabs/boards.



Glass mineral wool (glass fibre insulation).

Glass mineral wool (glass fibre insulation) is composed of fine glass fibres made from recycled glass, sand and other materials heated to high temperatures. It is supplied as quilts, loose-fill and blown products. It does not have moisture-buffering properties and may temporarily lose its thermal performance if it becomes damp or wet but, if it can dry out and has not become compacted, it will regain its insulating properties. Over time, slumping may occur, resulting in reduced performance.

Lightweight expanded clay aggregate is produced when clay is fired to a temperature of approximately 1150°C. It is granular and available in a variety of sizes. The process expands the clay and the resulting lightweight particles have a hard exterior skin and an air-filled cellular internal

structure. Like foam glass beads, it lacks compressive strength and its spherical form makes it difficult to walk on.

Lightweight expanded clay aggregate.

Perlite.

Stone mineral wool.

Perlite is white and ultra lightweight. Perlite ore expands up to twenty times its original volume when heated during manufacturing. It is naturally absorbent and is coated with a water-repellant when used as a loose-fill insulation. It is often mixed with other materials to increase vapour permeability and may be incorporated with a lime binder to produce insulating lime render.

Stone mineral wool is made primarily from volcanic rock melted at a high temperature. An important selling point is the material's extreme resilience to fire; it helps contain fire and prevent its spread. Stone wool is supplied in a wide range of forms, including blown, batt and roll. It maintains its shape, does not sag and is vapour permeable. Although it does not have the

moisture-buffering properties of natural products, this works in its favour for many applications – for instance, filling the cavity in modern wall construction.

Vermiculite is a naturally occurring mineral expanded at high temperature to produce aerated particles for use as loose-fill insulation. As it is highly hydrophilic (it absorbs and retains water), the material is not recommended for use in areas that are likely to be subject to any moisture.

Vermiculite.

Petrochemical materials

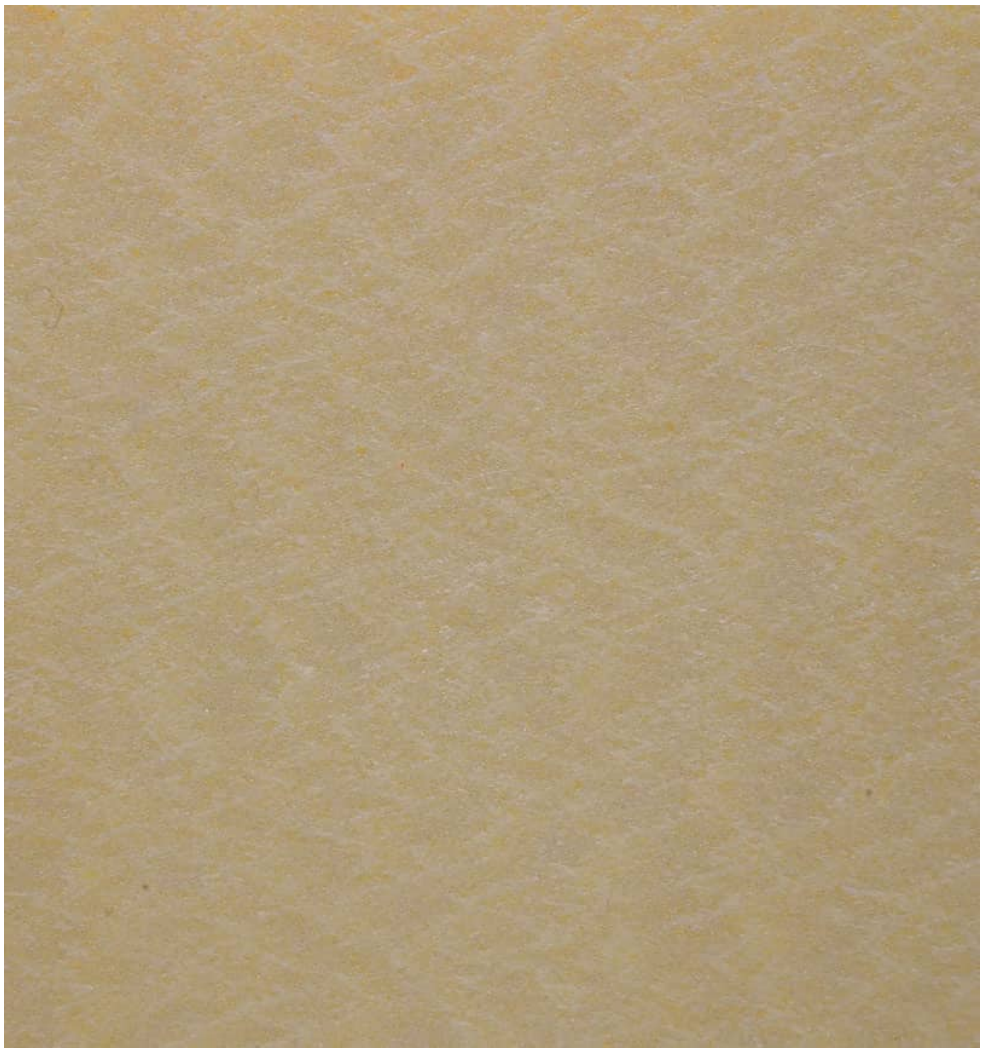
Petrochemical-derived insulation materials are non-biodegradable and may create toxic fumes when burnt. Although some are claimed to be breathable,

most are not and provide poor acoustic insulation. They are widely used in modern buildings, as they can provide high levels of thermal insulation relative to their thickness.

Expanded polystyrene (EPS) is supplied as a blown product in bead form – usually combined with a binding agent or adhesive at the point of use – or as boards. Although it is normally white, some EPS is silver-grey in appearance as it contains graphite to reflect heat and improve thermal performance. Direct contact with PVC cables should be avoided as there is a potential problem with plasticisers in PVC migrating into the EPS, causing it to shrink and the cables to become brittle.

Extruded polystyrene (XPS) is made by mixing polystyrene with a blowing agent under pressure. It expands into a foam and is formed into boards. Denser and stronger than EPS, it is able to withstand extra loading and impacts and is suited to use below ground. As with EPS, direct contact with PVC cables should be avoided.

Expanded polystyrene (EPS).



Extruded polystyrene (XPS).

Phenolic foam.

Phenolic foam is made by combining phenol-formaldehyde resin with a foaming agent and hardener. The rigid board material is faced on both sides with a foil that provides strength and improves thermal performance. The closed-cell structure of the foam resists moisture.

Polyurethane (PUR) rigid foam has been used since the 1960s as a high-performance insulation material.

Polyisocyanurate (PIR) is an improved form of PUR offering slightly higher thermal and fire performance and dimensional stability. The rigid board material is foil faced on both sides and the products are closed cell, so they resist moisture. Some products are known to shrink over time by 1–2 per cent.

Polyisocyanurate (PIR).

Capillary-active, rigid PUR foam panel.

Recycled plastic fibre wool.

Capillary-active, rigid PUR foam panels are marketed as breathable and have holes containing a mineral, capillary conductive filling. Their vapour permeability is poor compared to that of highly breathable natural insulation materials.

Polyurethane (PU) spray foam is liquid foam that expands, in some cases to many times its original volume, before hardening. Small handheld aerosol cans are sold for gap sealing and are often used during the installation of window and door frames. For precision applications, low or minimal expansion grades are available where the foam stays approximately at its extrusion size, making it ideal for filling cracks and small openings. Spray foam is also applied by specialist contractors to

cover large areas. In such applications it is generally non reversible and prevents the reuse of materials.

Recycled plastic fibre wool exploits duvet and pillow technology. The insulation uses polyester fibres and is manufactured in rolls from recycled plastic bottles.

Composite materials

Made up of various elements to provide specialised solutions, composite products tend to contain plastics and are not generally biodegradable.

Honeycomb foils are made of shaped polyethylene foams glued to aluminium-coated foils. Thermal performance is provided by a large number of low emissivity cavities and films.

Honeycomb foil.

Multi-foils consist of multi-layered reflective films sewn with foams to form thin insulation blankets that are lightweight and flexible. Some include breather membranes or vapour control functions. Multi-foils may require supplementary insulation with other materials.

Multi-foil.

Vacuum-insulated panels (VIPs) use the insulation of a vacuum contained within a board-shaped, gas-tight envelope to achieve high thermal performance with minimum thickness. Their effectiveness is reduced if the vacuum seal is broken.

Vacuum-insulated panel (VIP).

Getting the right contractor

Attention to detail is crucial to achieving good thermal insulation and airtightness. The more complex the system of insulation, membranes and tapes, the more conscientious the installer must be. Appoint a contractor who is not only familiar with the materials being used but who also understands the importance of attention to detail and the dangers of thermal bridging. Great care must be taken at every step and, ideally, the installation should be thoroughly checked before it is covered with final finishes. A contractor who is working to a fixed price may rush the job or hand it over to a less skilled person.

Poorly executed retrofits become apparent in snow. The area of melted snow indicates missing or badly installed insulation.

PIPE AND DUCT INSULATION

Insulating pipework and ductwork cuts heat losses, prevents condensation problems and improves the acoustic performance of the installation. Some ductwork is supplied pre-insulated. Lagging consists of pre-formed insulation tubes of varying sizes that are snapped or sleeved on. These

employ a variety of insulation materials, including closed-cell polyethylene foam, glass wool and mineral wool; some have a reinforced foil covering that incorporates a self-adhesive overlap, which helps to provide vapour control. Cold pipes and ducts must be protected by insulation that is impermeable to vapour to avoid condensation on their surface.

INSULATION FIXINGS

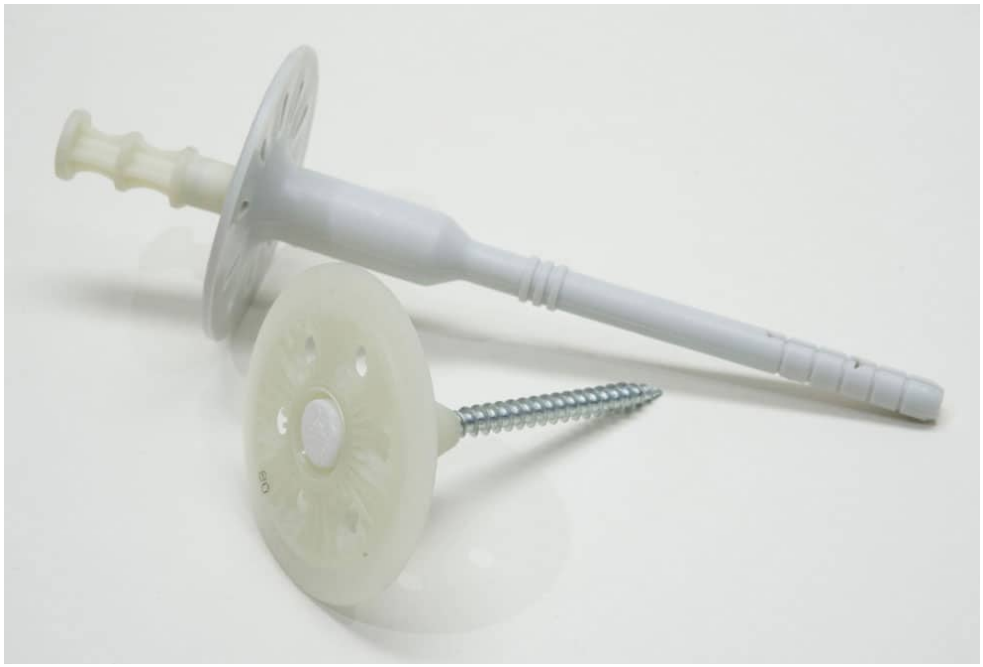
Care needs to be taken when fixing thermal insulation products, since metal fixings such as screws and nails that penetrate the material are likely to cause a thermal bridge. Where necessary, use specially designed thermally broken fixings, which generally have a plastic shield.

FIRE STOPPING

At all stages of a retrofit, you need to consider protection against the spread of fire. Fire stopping may be required within walls, floors and ceilings and where pipes, cables, conduits and ducts pass through openings made in the building’s fabric. A wide range of fire-stopping products is available and some also offer thermal insulation and reduced noise transmission.

Thermally broken fixings are vital when installing insulation.

Pipe insulation: foil-faced stone mineral wool (left); polyethylene (right).



Various types of thermally broken fixings are available, depending on the application.

MEMBRANES AND BARRIERS

Even a small amount of air movement through or around insulation materials will reduce their effectiveness. A carefully detailed plaster layer may provide adequate airtightness, but sometimes a separate membrane is

required. These impede air movement and have varying degrees of vapour permeability. If used incorrectly they can have unintended consequences, so extreme caution should be exercised when installing any type of membrane in a traditional building.

Although membranes are often installed only on one side of the insulation material, some circumstances require membranes to be installed on both sides to achieve maximum thermal performance. The family of membranes available is large. While many are technically advanced, some are used simply for waterproofing or to provide material separation. Where there is uncertainty over which product to use, consult the insulation system provider or membrane manufacturer to ensure the right choice is made. Crucially, the membrane selected should have the correct level of vapour permeability for that particular application, given the location and specific risks.

Any membrane will only perform properly if it is detailed and installed correctly. It is essential to use airtightness tapes, collars, sleeves and grommets to achieve continuity of the membrane across junctions and penetrations.

Any membrane may be punctured accidentally so it is vital to consider at the design stage how they can be protected from such eventualities. Importantly, the integrity of the building envelope should not rely on a membrane being installed perfectly.

Membranes are sometimes used to achieve airtightness, but inappropriate use can trap moisture.

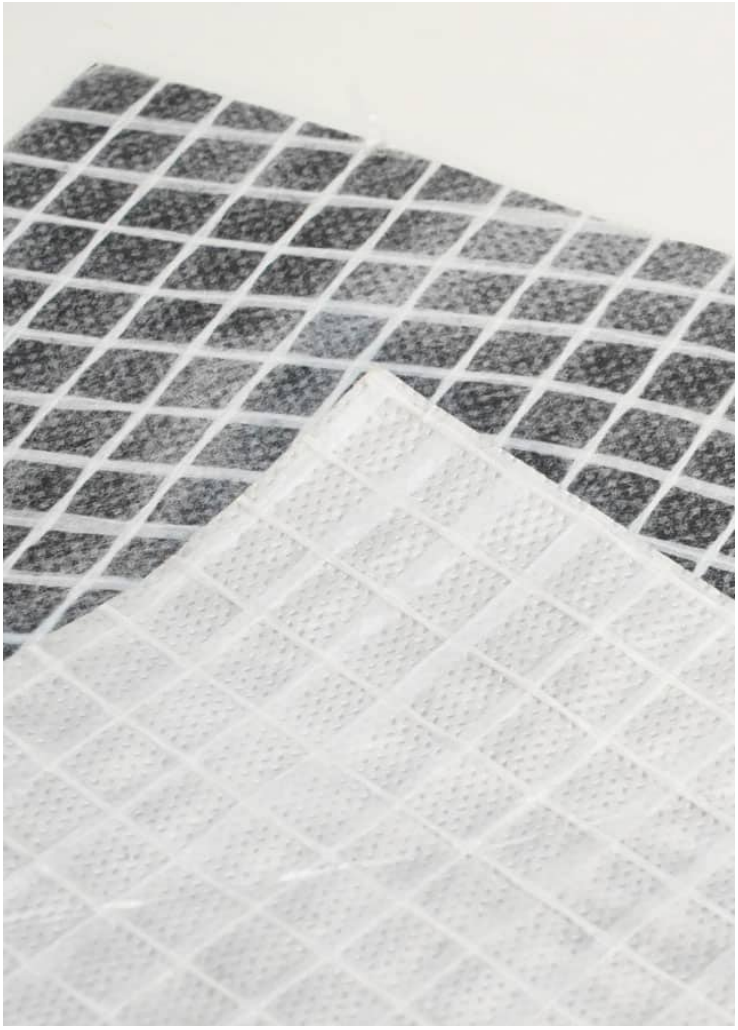
Windtightness membranes, also known as breather, breathable or vapour-permeable membranes, provide protection on the external, or cold, side of insulation. These membranes are typically employed under roof tiles or behind cladding and are increasingly used over loft insulation and under suspended timber floor insulation. They are designed to prevent both draughts and, in the case of walls and roofs, liquid water (rain) from passing through. They have high vapour permeability with an open weave that is large enough to allow water vapour readily to pass through, minimising the risk of moisture becoming trapped in the building fabric. The level of vapour permeability depends on the difference in vapour pressure either side of the membrane. Tear resistance is also an important feature of a windtightness membrane.

Airtightness membranes, also known as air and vapour control layers, vapour retarders and vapour check membranes, are installed internally on the warm side of insulation materials. These membranes are designed to

minimise the flow of warm, moisture-laden air from inside the building passing through into the body of the wall, roof or floor. They can be useful for reducing moisture build-up in cold voids with limited ventilation.

It is virtually impossible to prevent all vapour from breaching the membrane, due to the number of junctions, penetrations and inadvertent punctures that occur during the build process. Indeed, it would be dangerous to design a construction that relied entirely on a perfect vapour-tight membrane. For this reason, airtightness membranes have a degree of vapour permeability, which is measured by their diffusion resistance or vapour resistance. This allows small amounts of vapour to travel in both directions to prevent moisture that has leaked through the membrane from becoming trapped.

Failure of the airtightness membrane can result in a build-up of moisture, interstitial condensation and the potential for decay. The knock-on effects of installing an airtightness membrane should be carefully considered and may require alterations to the ventilation strategy to cope with the reduced vapour permeability of the fabric. For solid masonry-walled buildings, airtight membranes are unnecessarily risky, as a high level of airtightness can instead be achieved by a continuous layer of plaster.



Membranes are designed for specific applications, so must be chosen with care.

Intelligent membranes are designed to address the problem of the imperfect airtightness layer. They are fitted on the warm side of the insulation, and their vapour resistance changes seasonally, depending on temperature and humidity. During the winter months, the membrane has high vapour resistance – assuming it has been carefully installed. This prevents the majority of moisture from passing through internal surfaces, building up in the insulation layer and potentially leading to interstitial condensation as it cools towards the external side. In the summer months, when the vapour pressure is higher externally than internally, the vapour resistance of the membrane dramatically reduces. This encourages any moisture that has built up over the winter months to escape back through the internal surfaces and be naturally ventilated away from the structure. The risk of interstitial condensation during the winter, and sweating during

the summer, are both reduced, but intelligent membranes should not be relied upon to eliminate all problems.

The airtightness membrane being installed around this conservation style rooflight is designed to significantly reduce heat loss.

Liquid applied airtightness membranes are applied by brush or spray. They are designed to create an uninterrupted air- and vapour-tight seal over cracks and gaps. The products are marketed for their ability to perfectly follow the contours of the substrate and for their flexibility to accommodate some movement. They can provide localised treatment at difficult junctions but they may not be compatible when applied to breathable structures over large areas and could cause problems where wind-driven rain is an issue.

Removing them from the building's fabric in the future may prove problematic.

Airtight boards, such as specially designed, airtight, oriented strand board (OSB) and particle board products, can eliminate the need for membranes and may simplify the process of achieving airtightness and vapour control, while also offering structural properties. Joints are sealed using airtight tape.

Vapour barriers prevent the passage of any vapour or air. They are not generally suitable for old buildings, as they tend to trap moisture within the building's fabric.

Membranes: installation checklist

To work effectively, membranes and barriers must be installed correctly. Some products have printed cutting and laying patterns, making them easier and quicker to work with.

- Be careful not to puncture, tear or overstretch the material.
- Ensure it is laid with the right side out.
- Avoid leakage through stapling points; secure with double-sided tape.
- Check there is sufficient overlap.
- Avoid gaps, folds or bubbles at junctions.

Geotextile membranes provide soil separation, ground filtration and ground reinforcement. There are two main types: woven and non-woven. Although both allow liquid water through, woven geotextiles tend to be stronger and stiffer than non-woven types. Non-woven geotextiles generally offer superior filtration, so they are used where good drainage is required but where fine debris and soil must be prevented from entering the drainage system.

Damp-proof membranes (DPMs) are usually a strong, impermeable plastic membrane laid under concrete floors to resist rising damp.

Radon barriers protect against radon, a naturally occurring radioactive gas that is found in certain geographical areas. Prolonged exposure can cause health problems and specialist membranes are used to provide a continuous

radon barrier across the whole footprint of the building. It may be necessary to provide sub-floor ventilation with a radon sump, pipework and extract fan so that the gas is vented outside the building.

TAPES AND PRIMERS

Overlaps, junctions and penetrations, as well as the meeting points between building elements such as windows and walls, and around joist ends, pipes and cables, must be carefully sealed to maintain the continuity of membranes or barriers. Adhesive tapes are vital to this process, with the various products serving different functions depending on whether the requirement is airtightness, vapour control or waterproofing.

Expanding compression tapes

Tapes that expand from their compressed state are useful for closing gaps between window and door frames and surrounding masonry. Once unwound and applied, these tapes expand to fill a gap, sealing against uneven surfaces and accommodating joint movement. They are much cleaner to use than silicones and mastics.

Compression tapes expand considerably to fill gaps once released from the roll.

Tapes: checklist

Double- and single-sided tapes are available, with some having split backing strips to make installation easier. Pre-folded versions simplify taping around windows and doors and hand-tearable products save time. Any tape must have sufficient elasticity to accommodate structural movement in the substrate. A roller is sometimes used to apply even pressure during application.

Before purchasing tape consider the following questions:

- Does it offer the necessary adhesion for the job?
- How resistant is the tape to ageing?
- Can it withstand cold and hot temperatures?
- How easy is it to use?
- Does it offer the necessary flexibility and malleability?
- Is it sufficiently strong for the purpose?
- Can it be laid quickly without wrinkles or bubbles?
- Is it dimensionally stable?
- Will it be painted or plastered over?

It's important to choose the most appropriate tape for each application.

Primers

Designed to pre-treat rough and absorbent surfaces for airtight tape adhesion, paint-on primers may, for example, be used where membranes are taped to wood or masonry. They help maintain the airtightness and vapour control integrity of junctions where the bond must be strong, long-lasting and permanently elastic to allow for differential movement. It is important that glues and adhesives are appropriate for use with individual products.

GROMMETS, COLLARS AND SLEEVES

To achieve continuous airtight sealing, grommets, collars and sleeves are installed at penetrations made in the building's envelope for services such as pipes and cables. They are often self-adhesive and are used in conjunction with airtightness membranes and insulation boards.

A pipe grommet is taped to maintain the integrity of the membrane.

Burnt sand mastic provides a practical and pleasing junction between windows and masonry.

The decisions we make about materials are important for the future health of our buildings and their occupants.

ADHESIVES, SEALANTS AND MASTICS

Used variously to seal penetrations, create airtight junctions, bond surfaces together and fill gaps, a wide range of adhesives, sealants and mastics is available. Not all are flexible enough to accommodate significant differential movement.

Burnt sand mastic

Hardening slowly but remaining flexible, burnt sand mastic has been in use for at least 200 years to form joints between timber window and door frames and masonry. It is supplied in two parts – burnt sand and oil-driers – and mixed as required.

STANDING THE TEST OF TIME

Even with the most rigorous testing regimes, we must not forget that the only true measure of a material's longevity or compatibility is time. This is why we trust and understand lime plasters, clay bricks and timbers such as oak. We know that these traditional materials can easily last countless

centuries. Despite their apparent benefits, it is impossible to be so certain about the palette of more modern materials.

There is reason to be cautious. Asbestos was heralded as a wonder product at the end of the nineteenth century, but it took decades for its damaging impact on human health to be fully acknowledged. Today, off-gassing from certain materials is seen to be a risk, especially as buildings become more airtight, while the dust and fibres resulting from other materials have been called into question.

Materials and systems may fail to perform their intended design function and the expected thermal performance might not be achieved. We cannot be sure that they will not degrade or be incompatible and cause decay in traditional structures, so reversibility is an important consideration. It is vital that, when these products are introduced into old structures, they can be removed in the future without doing unnecessary further damage should they fail.

05 | ROOFS AND CEILINGS

In an uninsulated house it is estimated that a quarter of the heat lost is through the roof, so it makes sense that this part of the building envelope should be a high priority when improving overall thermal efficiency. Adding loft insulation is a relatively easy and cost-effective task; insulating attic rooms and sloping ceilings tends to be more complex.

Traditionally, the main purpose of a roof has been to keep the elements out; keeping heat in has tended to be a secondary consideration. Today a roof has to perform in all respects: it must resist wind and rain and it should incorporate a high level of thermal insulation and airtightness.

Energy-efficiency campaigns have frequently focused on persuading homeowners to upgrade their loft insulation. Often this work is inexpensive and straightforward and has a relatively quick payback period because of the reduction to energy bills that it achieves. Despite this, many houses still have surprisingly poorly insulated roof spaces. Others have seen ill-conceived insulation strategies that are inefficient or even hugely damaging to the building’s fabric.

Roofs can become energy generators, but sometimes at the expense of aesthetics.

Incorporating insulation into an old roof and reducing air leakage from the rooms below requires the use of appropriate methods and materials. An uninhabited loft space should be treated in a very different way to an attic containing living accommodation, while an ancient timber-framed roof may need a solution totally at odds with a loft conversion in a Victorian terrace. Any solution should take account of the danger of condensation resulting from water vapour, as this can cause major problems if left to chance.

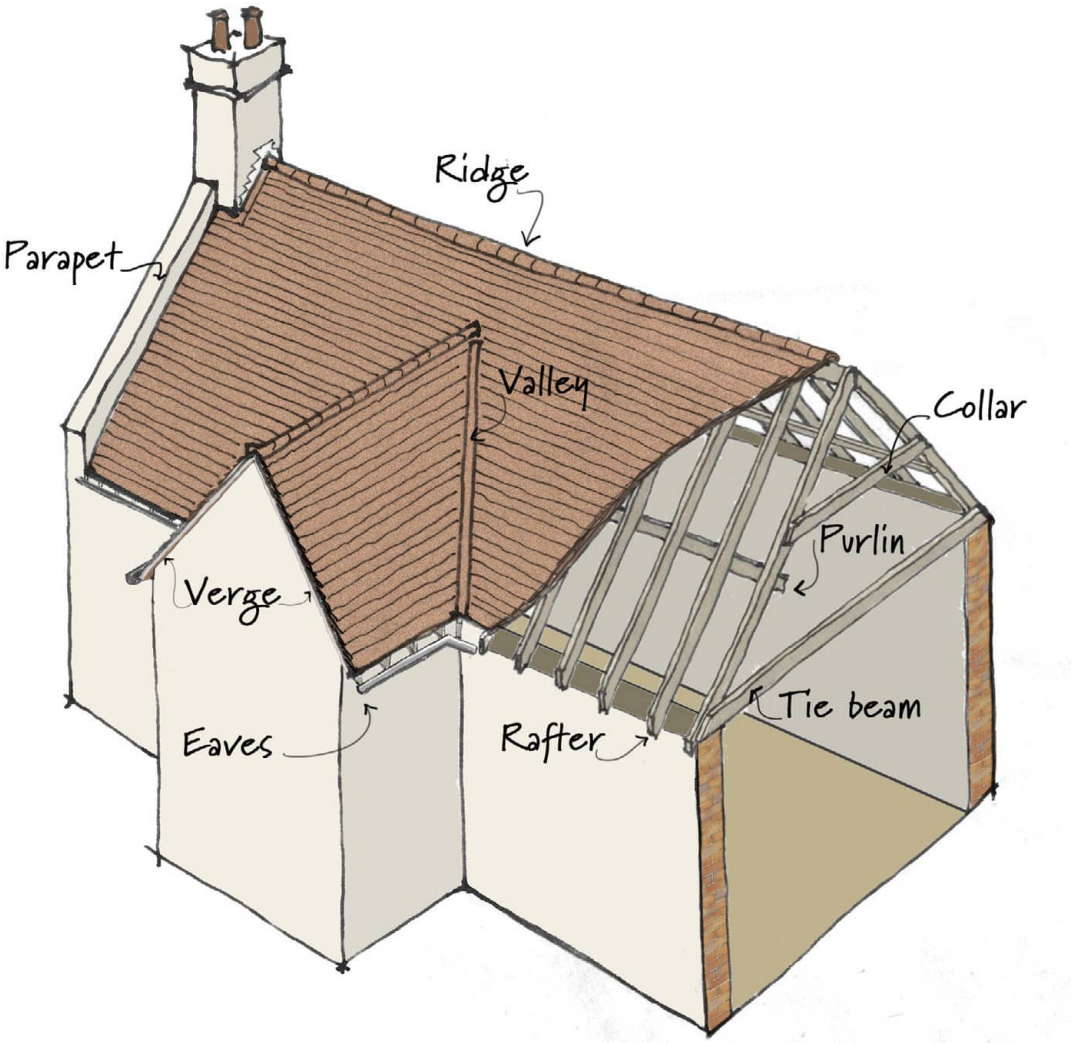
BUILDING REGULATIONS

The Building Regulations require roofs of existing buildings to be upgraded to comply with current U-values under the circumstances listed shown here, and, more specifically:

- When the roof space is being converted to a habitable room (but not if the habitable room already exists).
- When more than 50 per cent of the roof is to be re-tiled.

Even if the circumstances above apply, a thermal upgrade is only required if the existing roof performs worse than the ‘threshold U-value’.

Roofs are not only a first line of defence against the weather, they also play an important role in the battle against heat loss. Where roofs fail, the whole building is at risk.



The principal elements of a roof.

Safety first

When working in roof spaces, always think about safety:

- Although it is not necessarily required with natural insulation materials, it is always sensible to wear a good-quality face mask and gloves. Loft spaces are frequently dusty and may contain old insulation materials or asbestos, as well as the remains of wildlife and bird, bat and rodent droppings (See Health and safety, shown here).
- Ensure there is sufficient light to work and carry a torch.
- Check you have safe access and that ladders are properly secured.
- Before stepping into the space, ensure that it is safe to do so and that the joists are sound and able to carry your weight. Never walk between the joists.
- Carry a mobile phone and let someone know that you are up there, especially when working alone.

WHAT TO CONSIDER

Always establish the best way to insulate your particular roof from the outset and discuss technical solutions with manufacturers and suppliers – but beware of advice that is not impartial. If necessary, appoint an architect or surveyor with an understanding of traditional, breathable structures to inspect the roof fully. Numerous factors should be considered before insulating roof spaces, including:

- Are you planning to leave the roof space ‘cold’? If you are, insulation at ceiling level is by far the easiest and cheapest option, but be aware of unintended consequences (See Upgrading insulation: unintended consequences, shown here).
- How is the roof ventilated and is there a condensation problem?
- Is the roof space occupied or are you planning a loft conversion in the future? Plan ahead and think carefully how best to insulate the roof.
- Is the roof in poor condition? If so, it may be more economical to re-tile and insulate at the same time.
- Will the proposed insulation solution raise the line of the roof? Carefully consider the implications, especially if your house is attached to another house.

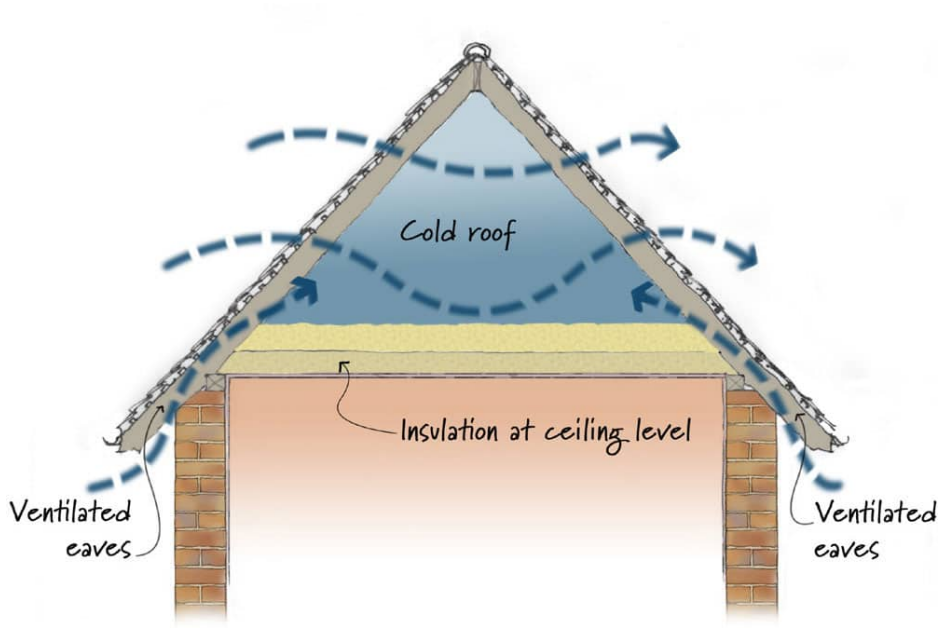
- Is there a danger of thermal bridging due to dormers, parapets or valley gutters? Never leave your roofer to find a solution to these details.
- Is the roof an historic structure and does it contain ‘torching’ (plastering to the underside) of the tiles or slates? If so, more sensitive solutions will be required.
- Will the work be above fragile historic ceilings? Screws, or possibly nail guns, rather than hammer and nails, will minimise vibration.

Re-tiling will generally require building regulations approval.

The three principal types of roof space

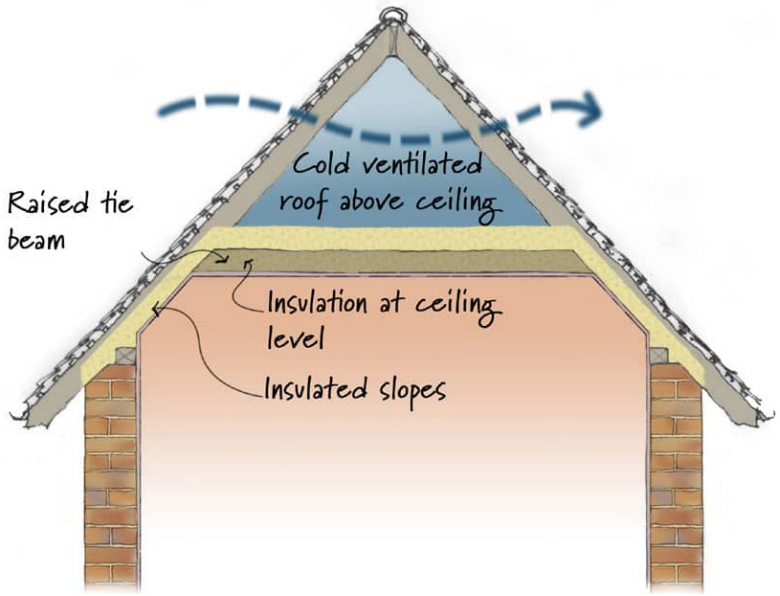
COLD ROOF

A clear ventilated roof space, which remains uninhabited and where the rafters are exposed on the underside. In such cases, loft insulation involves choosing a suitable material to lay above the ceiling of the habitable rooms below (See Horizontal ceiling insulation, shown here; See Upgrading insulation: unintended consequences, shown here).



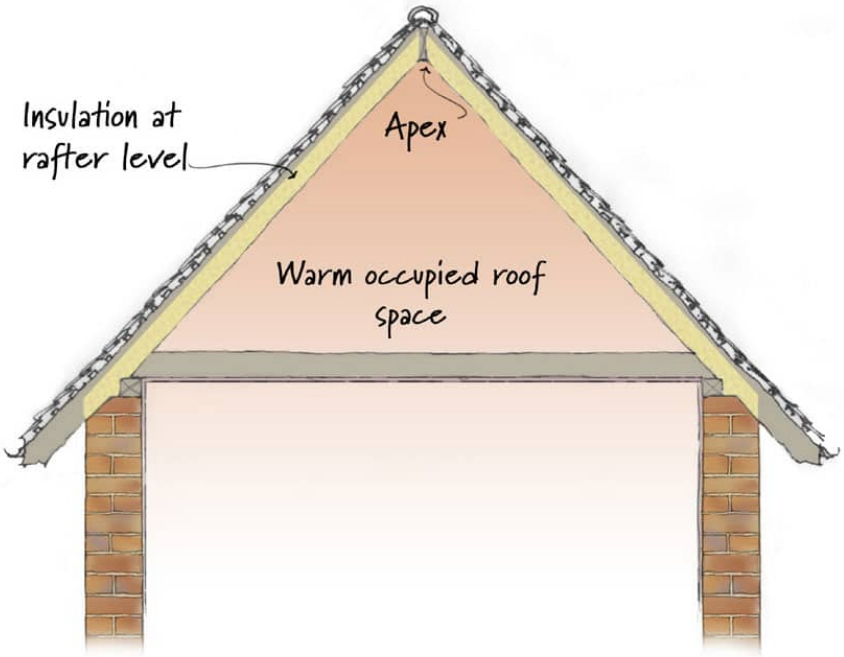
SEMI-OCCUPIED ROOF

A combination of a warm roof and cold roof, typical in cottages. The tie beams are raised to give the habitable room below more headroom, resulting in areas of sloping or ‘coombed’ ceiling, while the loft space above remains cold.

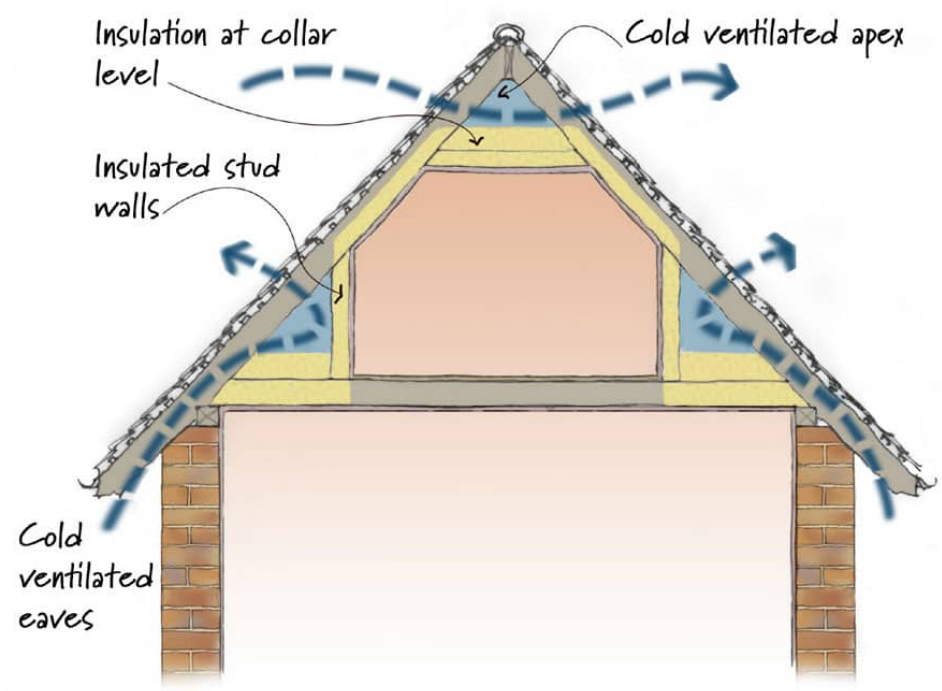


WARM ROOF

An insulated roof space containing an attic room or loft conversion. Old attic rooms often contain no insulation other than that provided by the thickness of the lath and plaster ceiling. When it is upgraded, the insulation can be added along the rafter line. The example shows the habitable space is clear to the apex and the eaves at the sides.



More commonly, stud walls have been constructed to create a vertical wall – with an eaves void behind – and the collars have been plastered, forming a small area of flat ceiling. If the house was originally designed this way, the plasterwork may be historic lath and plaster. Or, the loft space may have been converted into a habitable room in recent years (See Rafter-level insulation, shown here).



A typical Scottish cold roof space with timber sarking boards over the rafters.

A cottage bedroom with a coombed or sloping section of ceiling which, unless the roof is thatched, is notoriously difficult to insulate.

An original attic room in a nineteenth-century house. The low vertical wall to the left is a stud partition with lath and plaster finish, containing an eaves void behind.

HORIZONTAL CEILING INSULATION

For cold roofs where roof spaces are unoccupied, insulation is generally laid above the ceiling. To maximise the efficiency of the insulation, the work must be carried out carefully and with a full understanding of the issues and potential pitfalls.

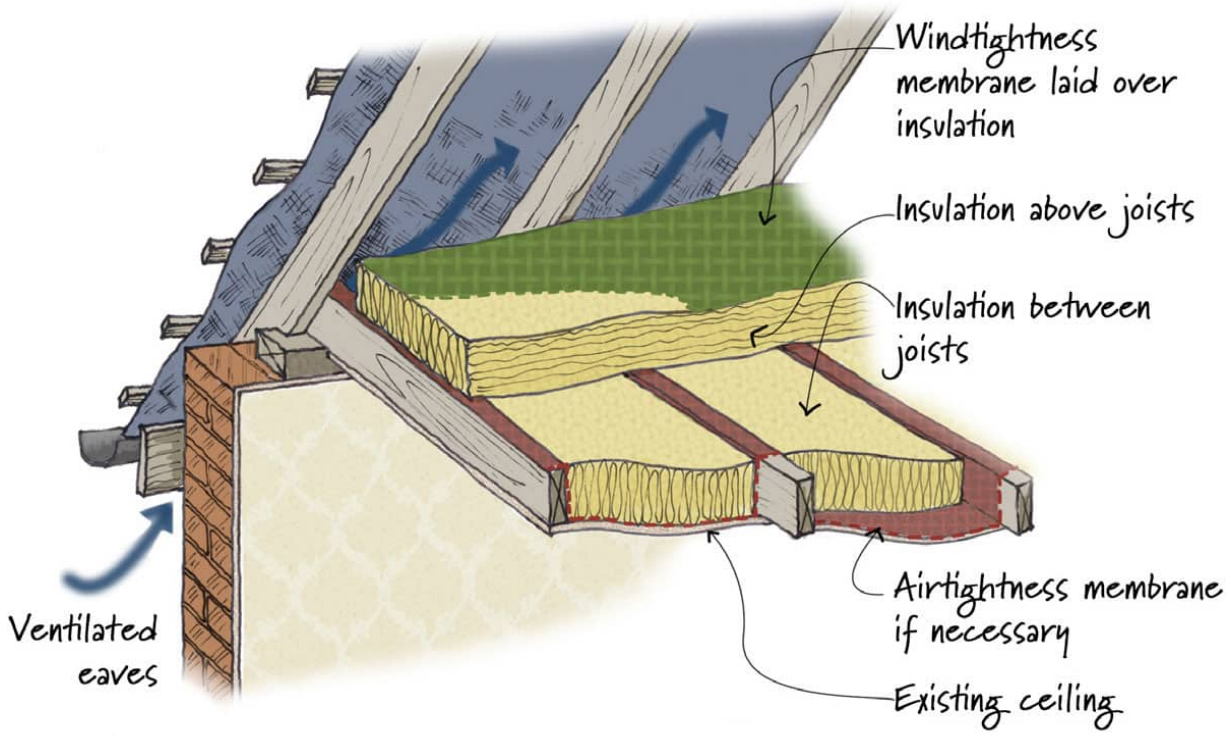
Loft insulation: before you start:

- Monitor and check the space for bats and nesting birds. Where they are present, you may have to modify how or when you carry out the work, as they are protected by law (See Wildlife and buildings, shown here).
- Use a large board to spread your weight over several joists.
- Clean the space, removing any items or debris.
- It is usually best to remove and discard old insulation and start again, but find out first what it is. Some are irritants and certain materials, such as asbestos, are hazardous (See Contamination, shown here).
- Take care not to damage the ceiling's upper surface. If you have a lath and plaster ceiling, the nibs of the plaster should be visible and gripping the laths. These nibs are important and must not be broken off, as they support the ceiling.
- Where older electrical installations are present, get the system checked.
- Try to ensure all first-fix electrical work has been completed. Where possible, position electrical junction boxes so they can be accessed without disturbing the insulation in the future – gaps and voids created by moving the material will reduce its effectiveness.
- Where possible, cables should not run under insulation because of the fire risk from overheating.
- Install any mechanical ventilation before insulation is added.
- Seal all penetrations to the ceiling structure, including gaps around pipes, cables and light fittings (See Minimising ceiling penetrations, shown here).

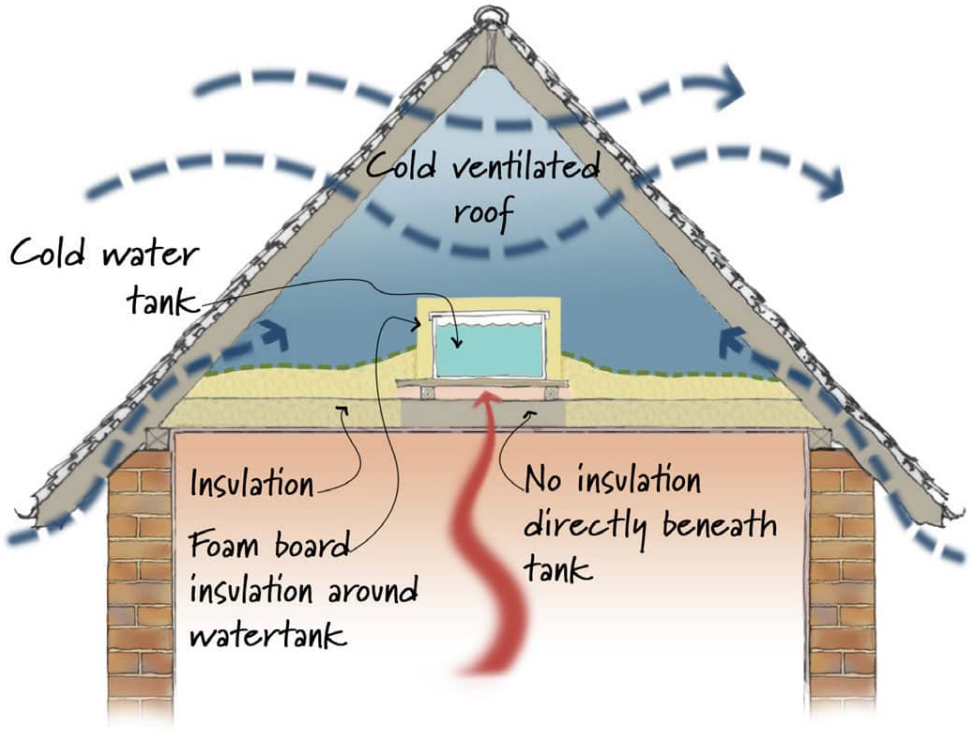
There are three main forms of material used to insulate above a horizontal ceiling: quilt, batt and loose fill. Rigid board insulation is not recommended; it is difficult to cut to size between joists, leaving gaps round

the edges, and does not sit snuggly over a lath and plaster ceiling (See Chapter 4, Retrofit materials).

Take care not to damage ceiling plaster nibs when working from above.



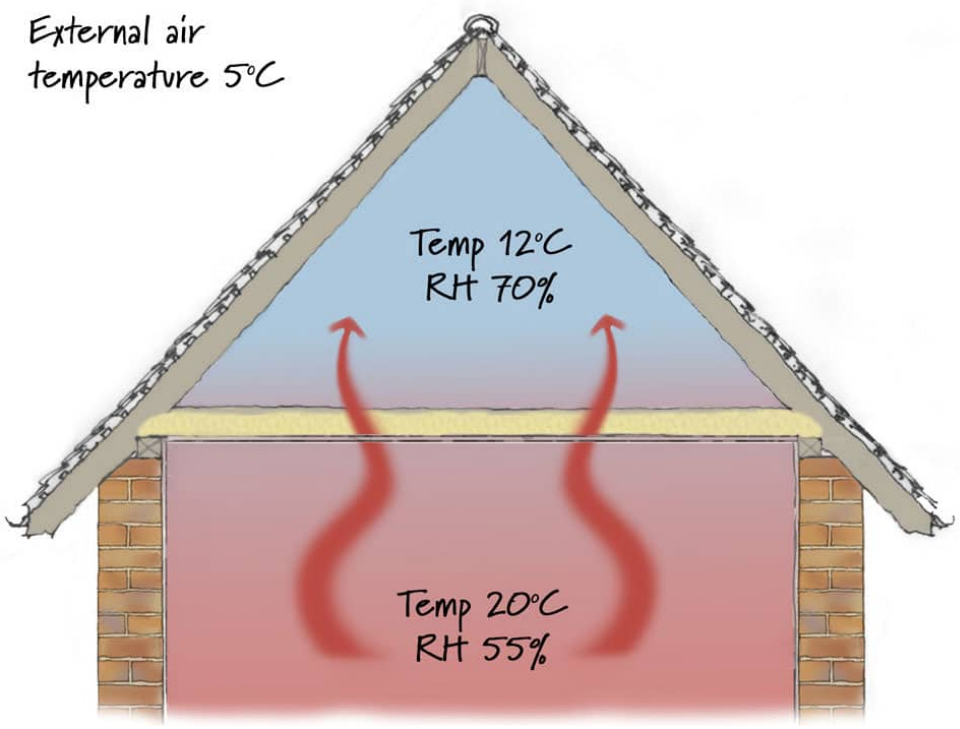
Address breaches at ceiling level or, if this cannot be achieved by any other means, consider laying an airtightness membrane. Quilts or batts are laid between joists, minimising any air gaps. Make up the necessary thickness of insulation with a second layer, laid at 90 degrees to the first. Finally, lay a windtightness membrane over the insulation to maximise efficiency.



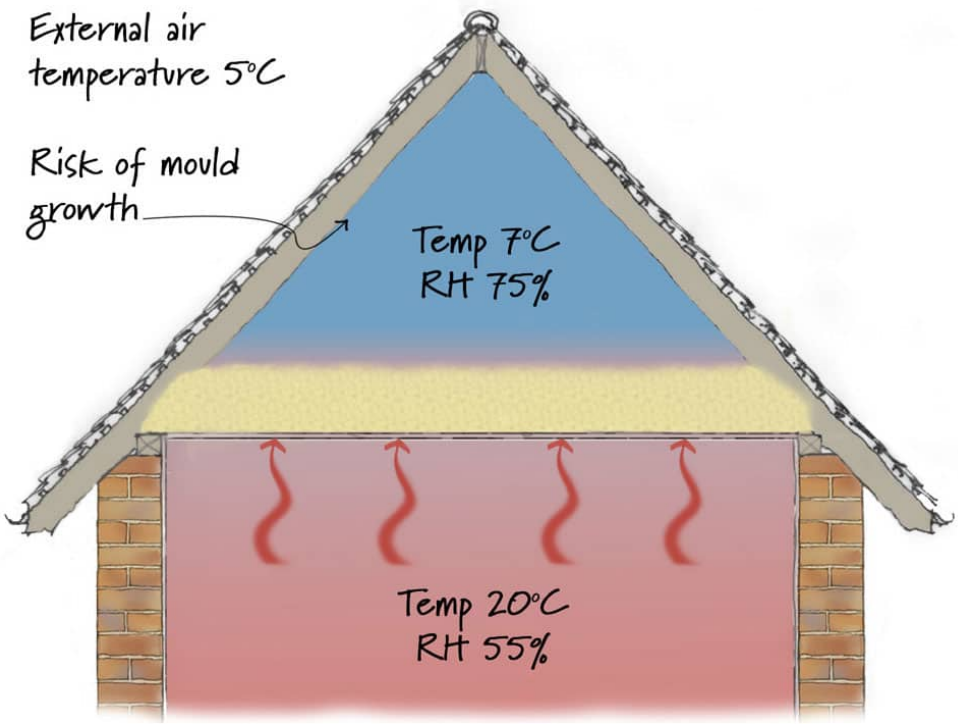
Tanks in roofs should be carefully sealed and insulated; foam board is an ideal material for this. To avoid the water freezing, do not insulate the floor directly under the tank.

Upgrading loft insulation: unintended consequences

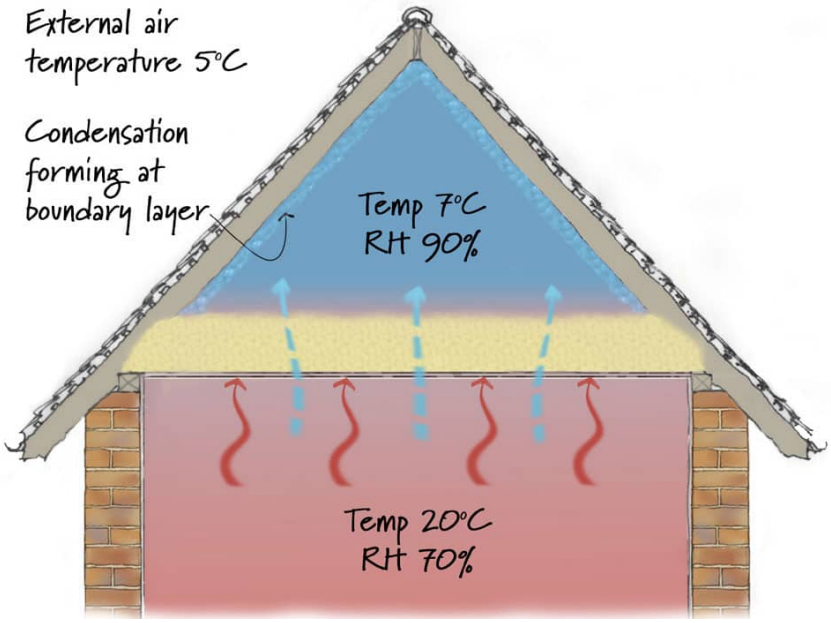
The following diagrams indicate typical scenarios when insulating a loft space.



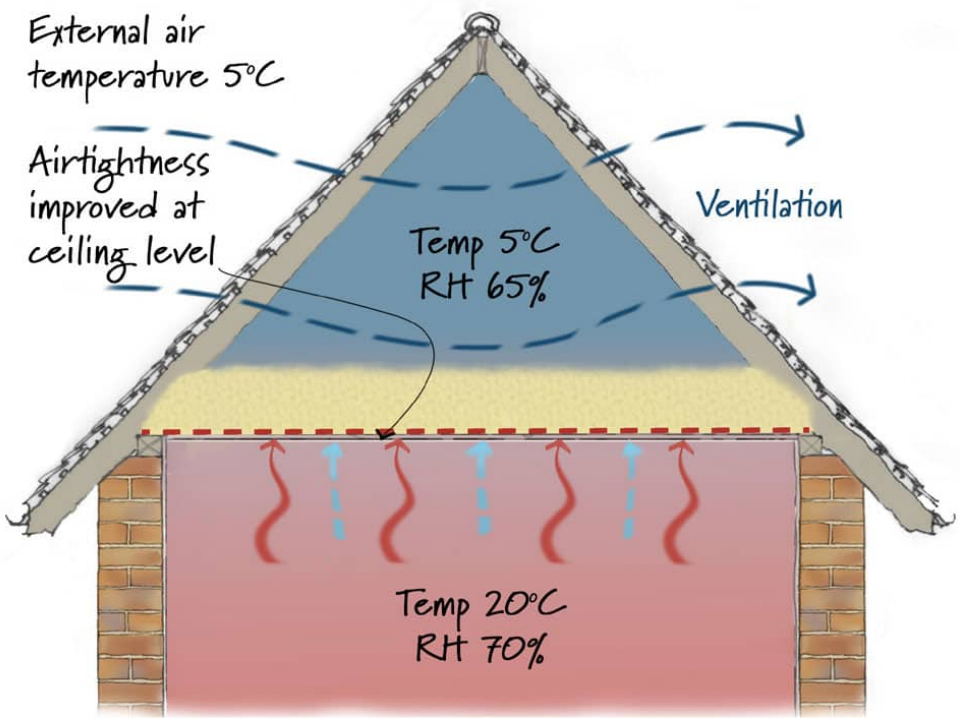
1. MINIMAL LOFT INSULATION: A typical home during the winter when the external temperature is 5°C. Internally, the house is heated to 20°C and has a healthy relative humidity (RH) of 55 per cent. A minimal layer of poorly fitted loft insulation is inadequate to prevent significant heat loss flowing through the bedroom ceiling and warming the loft space above. In this instance, the temperature of the loft is 12°C and the RH 70 per cent.



2. 300 MM LOFT INSULATION ADDED: Loft space insulation has been increased to 300 mm, largely blocking the heat flow rising from the bedroom. As a result, the loft space temperature will reduce, causing the RH to rise as colder air holds less water vapour. In this instance, the RH in the loft has risen to 75 per cent. The threshold RH for mould growth has been estimated at 73 per cent, although some claim it could be even lower: items stored in the loft are now at risk from mould forming on the surface.



3. A SPIKE IN RELATIVE HUMIDITY: Cooking, showering or increased occupancy could cause a temporary spike in RH, in this example raising it from 55 to 70 per cent. Water vapour will pass through any ceiling level leaks into the loft space. The lower temperature within the insulated loft will cause the RH to rise further, possibly peaking at over 90 per cent. The temperature just below the tiles and felt, known as the 'boundary layer', is influenced by the outside temperature and is often colder than the rest of the loft. This could fall to 5ºC or 6ºC, pushing the RH at the boundary layer to 100 per cent, causing condensation to form on the underside of the tiles or felt.



4. INCREASED VENTILATION TO LOFT SPACE: To prevent condensation and mould growth forming within the loft space, look at ways of improving airtightness at ceiling level to minimise water vapour passing through. Increased cross ventilation will help reduce the RH, as will the use of moisture-buffering forms of insulation. If in doubt, fit a sensor to monitor environmental conditions and inspect your loft regularly over the colder months.

Minimising ceiling penetrations

Any breach in the ceiling that allows air leakage and the passage of water vapour is likely to result in condensation in the loft space. To reduce this problem, some specifiers recommend that an airtightness membrane is laid over the ceiling and around the joists to form troughs, before insulation is fitted as shown in the diagram bottom left of shown here. In reality, it is difficult to lay, and gaps are often better addressed by other means. Start by filling any cracks to the ceiling, and the junction between the ceiling and the top of the wall.

Loft hatches are the main breach at ceiling level and can significantly compromise insulation and airtightness. It is recommended that a proprietary loft hatch unit is fitted that complies with current building regulations, incorporating both insulation and airtight seals.

Recessed light fittings that breach ceilings cause similar problems, particularly when fitted in bathrooms, shower rooms or kitchens, where they can allow a large quantity of water vapour to pass through (See Recessed light fittings, shown here).

Frequently installed specifically to extract moist air, ventilation fans are another concern. Often they are poorly installed and not sealed where they penetrate the ceiling. In addition, ducting passing through the loft space can leak, allowing moist air to be vented directly into the cold roof void. If this defect is left unattended, it leads to severe condensation and potentially dry rot, so it is vital to ensure that fans discharge effectively to the outside (See Ventilation, shown here).

Proprietary loft hatches that are designed to meet building regulations will be insulated and airtight.

Laying insulation quilt

- Choose a good-quality insulation product, ideally one that is moisture-buffering and able to absorb moisture vapour without slumping. Natural quilts are generally superior to man-made materials.
- When fitting the quilt between joists, where possible buy a product that comes in the correct width to save cutting.
- If the joists are random widths apart – as is common in old buildings – carefully cut, rather than rip, the quilt so that it is slightly wider than the space; this will ensure that there are no gaps around the edges. Ask your supplier to suggest a method of cutting the quilt and ensure you have the correct tools.
- The quilt should lie flat against the top of the ceiling, minimising air voids.
- Roof eaves are often poorly detailed but this is an important area to get right, otherwise thermal bridging and mould growth are likely to occur. Insulation should be continued to the eaves and, if possible, run over the wallplate and down the rafters, but this must not block eaves ventilation.
- Separate the insulation from any damp masonry or chimney stacks using a suitable membrane.
- Once laid, cover the insulation with a windtightness (breathable) membrane, taping any overlaps. As well as keeping it clean from debris and dust, this will prevent air movement within the insulation and maximise its thermal performance. A membrane above will also reduce draughts from the ventilated roof space leaking into the room below.
- Consider fitting permanent crawl boards down the centre of the roof space. These should be raised to allow adequate insulation to be laid beneath.

Laying loose-fill insulation above a ceiling

Cellulose fibre is the most commonly used loose-fill insulation in loft spaces. The insulation is pumped in via a hose and can be laid to any thickness, but 300 mm is a common depth to comply with current standards. When blown, it will retain its form simply under its own weight and is not restricted to the depth of the rafter to contain it. It is typically laid 15 per cent deeper than required to allow for settlement. If old quilt insulation is present, it may be left in situ with the cellulose fibre blown

over the top, avoiding the task of disturbing existing insulation and the accumulated dust. It is essential to keep the eaves area clear, particularly if this is a ventilation route. It is also important to ensure the cellulose fibre does not touch the underside of the roofing felt. This is achieved by tapering off the thickness around the perimeter.

Laying sheep's wool in a roof space. In certain circumstances, an airtightness membrane would be installed beneath the insulation quilt.

Roof membranes and ventilation

Ventilation is crucial in roof spaces, otherwise condensation may form which can lead to the decay of timber roof structures if left unchecked.

By the mid-twentieth century, non-breathable bituminous felts were being incorporated under slates and tiles. This system relied on a ventilated roof space beneath, otherwise they were vulnerable to condensation forming on the underside due to warm moist air rising and hitting the felt's cold surface.

In recent years, breathable roofing membranes (BRMs) have become the norm. These block liquid water from above but allow water vapour to pass through them from below, provided they are fitted correctly. They also require an adequate vapour pressure differential between the loft space and the external environment to force vapour through. In reality, they are often incorrectly installed. Unlike non-breathable bituminous felts, BRMs require a counter-batten to be fitted above and along the line of the rafter. The roofing batten is then fixed at right angles to this, and a ventilated void is created that can evaporate any vapour passing through the BRM. Failure to install a counter-batten can result in condensation, so always check the manufacturer's instructions; do not rely on your roofer to do so.

Some suppliers claim that additional ventilation is not required at eaves or ridge, although this may be a risky strategy where there are high levels of moisture vapour.

Regardless of the felt used, the first step is to avoid condensation problems by minimising the moisture vapour reaching the roof void (See Minimising ceiling penetrations, shown here). It may also be necessary to fix vents through the tiles or slates where air circulation is restricted, particularly if condensation is forming on the underside of the tiles.

There are a variety of under-tile venting systems that can be incorporated during re-tiling or slipped into position without stripping the roof. Some systems are more visually intrusive than others, so shop around to find the most inconspicuous product when the roof is viewed from the ground. Eaves and ridge ventilators may also be necessary to encourage maximum cross-ventilation.

If you are stripping the roof and recovering, or creating a room in the roof, you may be required to fit roof ventilation under the Building Regulations. Ask your building control officer for advice.

Slates incorrectly laid over a breathable roofing membrane. The counter-batten has been forgotten; this can lead to condensation forming under the slates.

A counter-batten should always be used above a breathable membrane, creating an actively ventilated void to allow the evaporation of water vapour rising through.

Where non-breathable felts are being retained, use small lengths of wood – typically 150 mm long – with a screw sticking out, pushed down between the overlapping edges of the felt. A proprietary lap vent can also be used. This will force the layers of felt apart and create a series of gaps to assist with ventilation and minimise condensation. In exposed areas, this detail could increase the risk of wind uplift to the tiles so should be avoided.

Plastic vents that look like tiles can be installed to further ventilate roofs where condensation is potentially an issue. These can also be used in certain situations to

terminate soil and vent pipes.

An attic bedroom with rafter-level insulation.

Creating storage areas in loft spaces

Take care not to overload your joist structure when using the loft for storage:

- Where possible, design a storage platform that is independent of the joists below and instead bears on load-bearing walls or beams.
- If fitting insulation at ceiling level, ideally with a windtightness membrane above, leave a 50 mm gap between the underside of the deck and the top of the membrane/insulation. It may be possible to fit the board directly over the insulation instead of using a windtightness membrane, but there is a risk of condensation, particularly where ventilation in the loft space is limited.
- Monitor relative humidity in the loft space, especially if you are increasing the insulation at ceiling level as this could result in mould growth (See Upgrading insulation: unintended consequences, shown here).

Bats and membranes

There is growing concern that most modern breathable roofing membranes cause a serious threat to bats. They are made from non-woven, spun-bonded filaments that fluff up when they come into contact with sharp bat claws. The bats become so entangled with the loose filaments that they cannot escape and eventually die. Certain modern bituminous felts contain polypropylene filaments (for example, type 5U) and pose a similar risk to bats.

The problem is so great that such membranes are not permitted on roofs where bat activity is evident. Instead, traditional bituminous felt reinforced with hessian (type 1F) remains a suitable alternative (See Wood fibre sarking boards – over rafters, shown here). New breathable membranes are available that claim to address the bat problem. These are manufactured with loose laid fibres that are weaker, but their durability in the longer term is not yet known.

RAFTER-LEVEL INSULATION

For warm roofs where roof spaces have been converted to habitable rooms, the insulation is fitted to the sloping pitch along the line of the rafters. There are various ways of installing insulation: above the rafters, below the rafters, in between the rafters or a combination of these. The best position technically is above the rafters, but this is not always practical. This can only be done by carefully stripping the tiles or slates so, if you are not re-tiling your roof, insulation to the sloping ceilings must be fitted from inside the loft space.

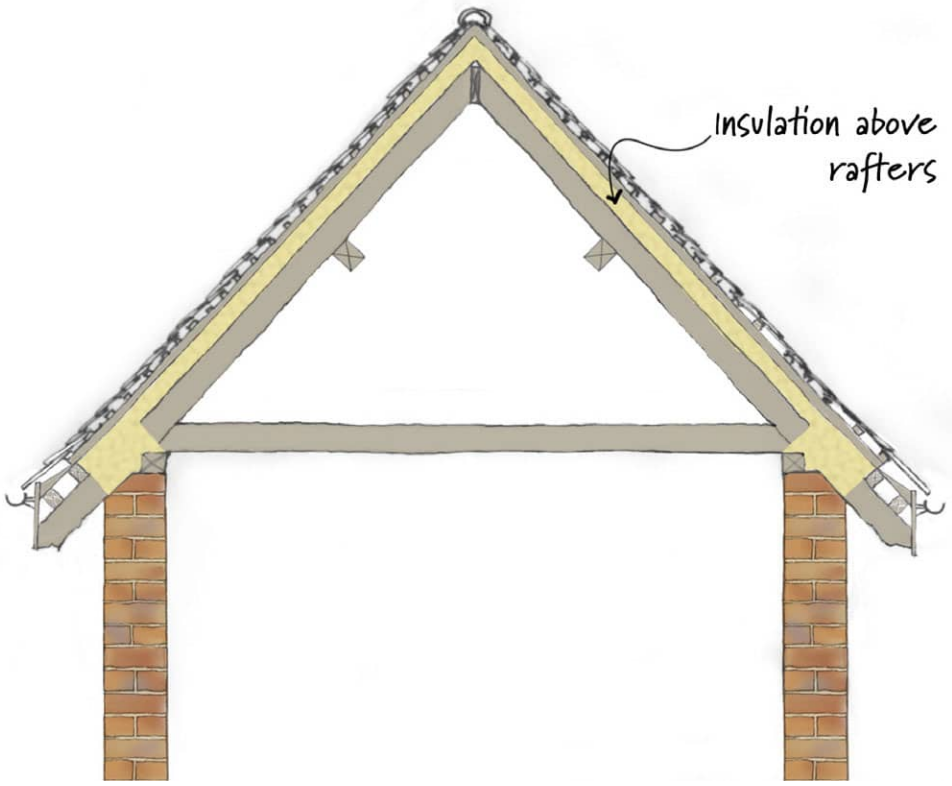
Before embarking on any roof insulation, ask yourself, ‘How long will it be before the roof needs re-tiling?’ If the roof’s future life is relatively short, it may be better to opt for the long-term solution: strip the roof, insulate above the rafters and re-tile the entire area.

Rafter-level insulation – access from above

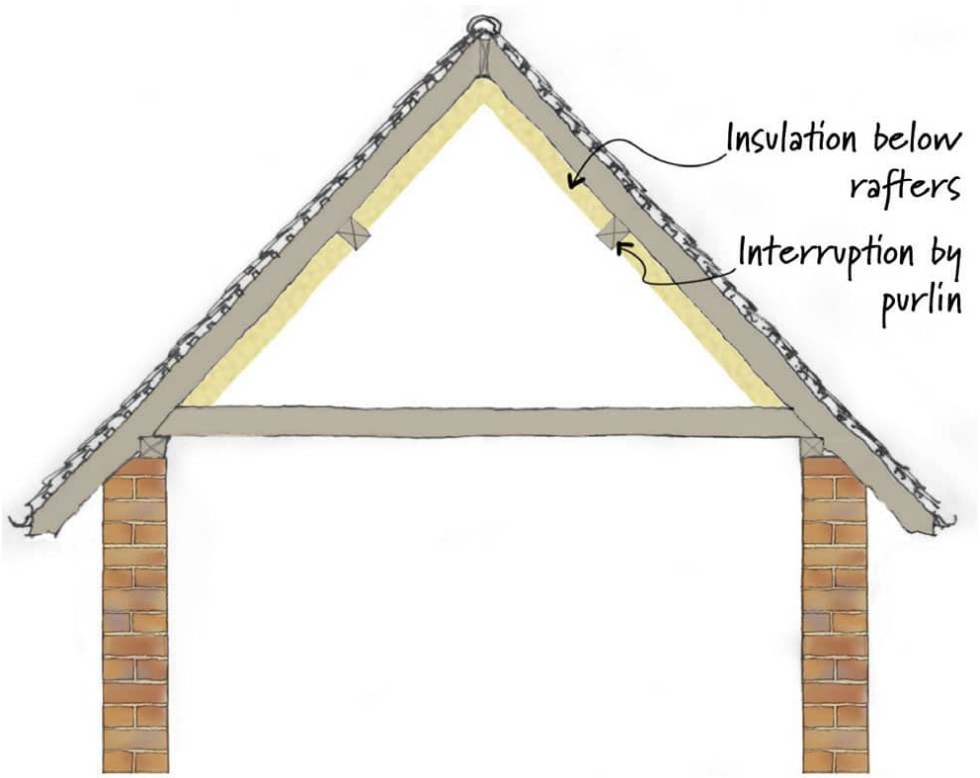
If re-tiling work is being carried out and scaffolding is in place, it makes sense to insulate an attic room from above. This minimises any disturbance to the room and is an important consideration if the rafters are plastered on the underside, particularly if the plaster is historic.

Over-rafter insulation takes extra time and may require a temporary roof to safeguard the structure beneath. This is particularly relevant for larger roofs,

works carried out during winter months and where there are decorative ceilings below, but will add considerable cost to the project.



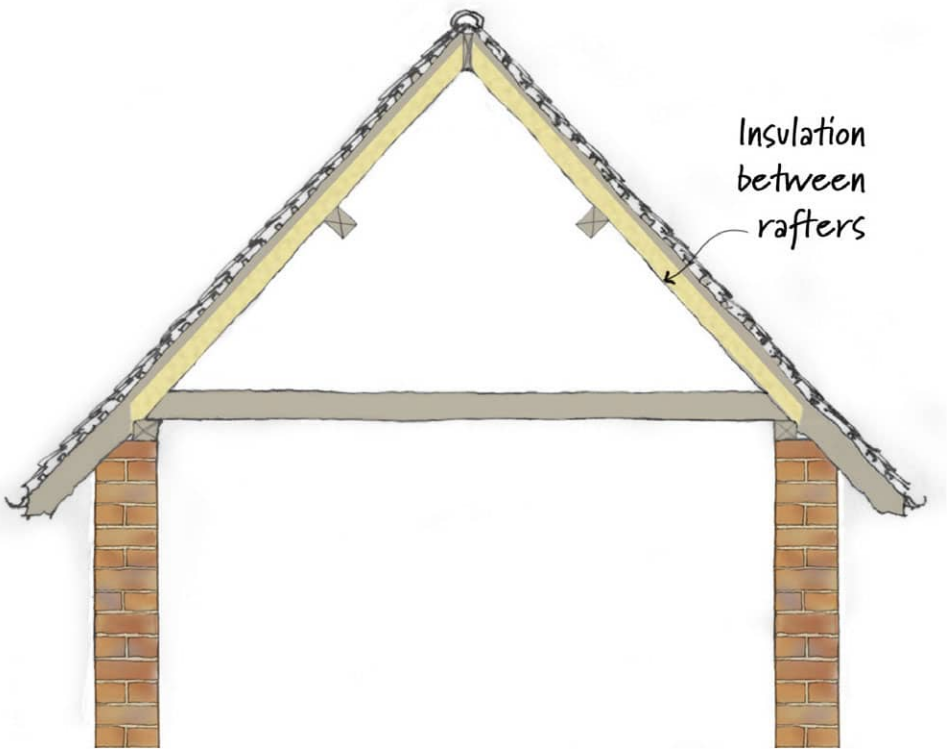
When roofs are insulated at rafter level (rather than ceiling level), careful consideration should be given to the position and type of insulation used. Often two of the following solutions are combined in order to achieve adequate U-values. Insulation above the rafters is technically the best, but it will raise the roofline and can only be done if the roof covering is being renewed.



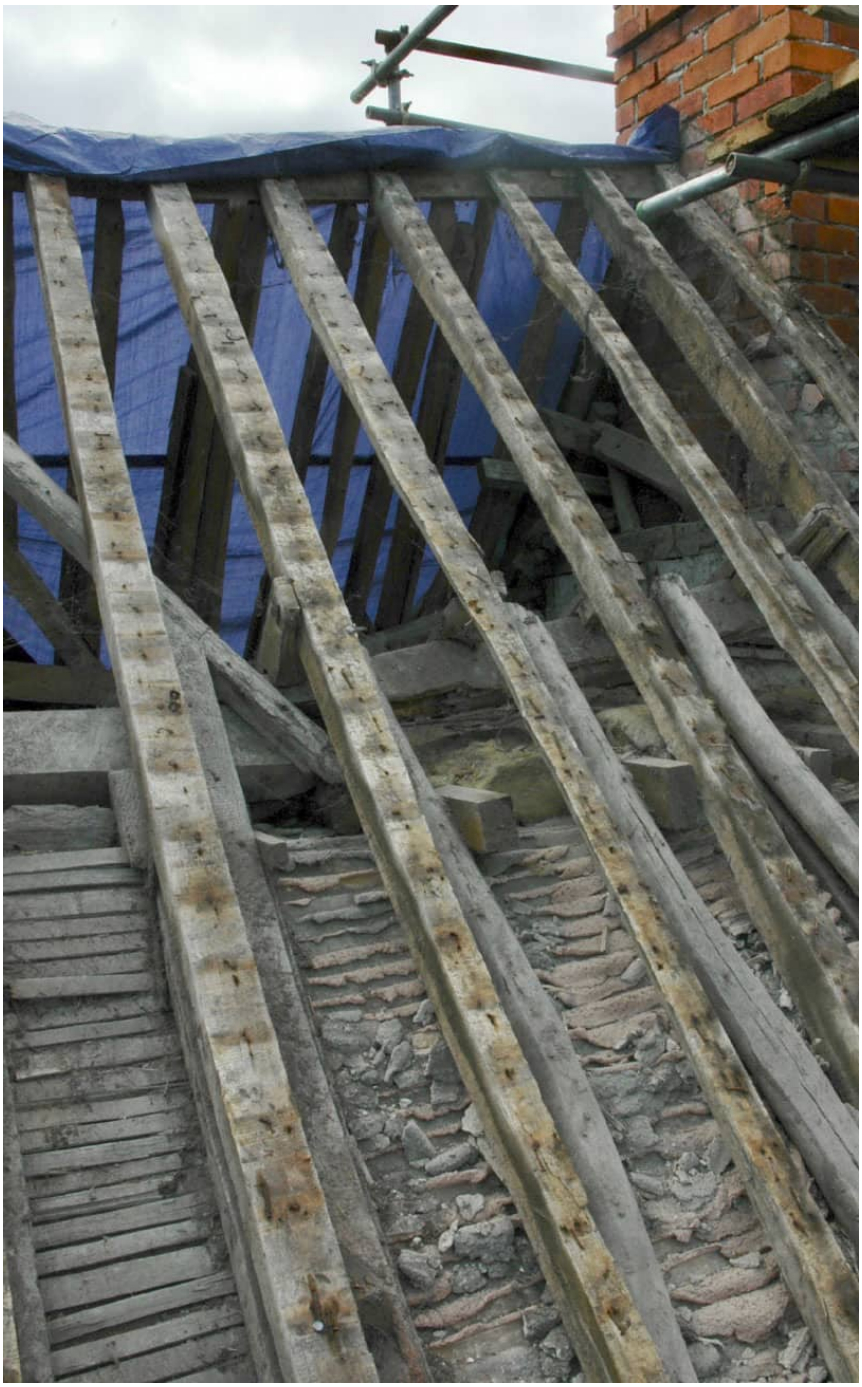
Insulation below the rafters can result in space being lost within the attic room. It is also subject to cold bridging due to interruptions such as purlins.

Insulation batts between rafters

If the rafters are deep enough, a reasonable U–value may be achieved by laying wood fibre batts, or similar insulation, to fully fill the space. This should be cut carefully, slightly larger than required, to form a compression fit to minimise gaps.



If installing insulation between the rafters, the escape of moisture vapour should be considered. Where the space is fully filled with insulation, this can be achieved by ensuring that the membrane or sarking board above is breathable.



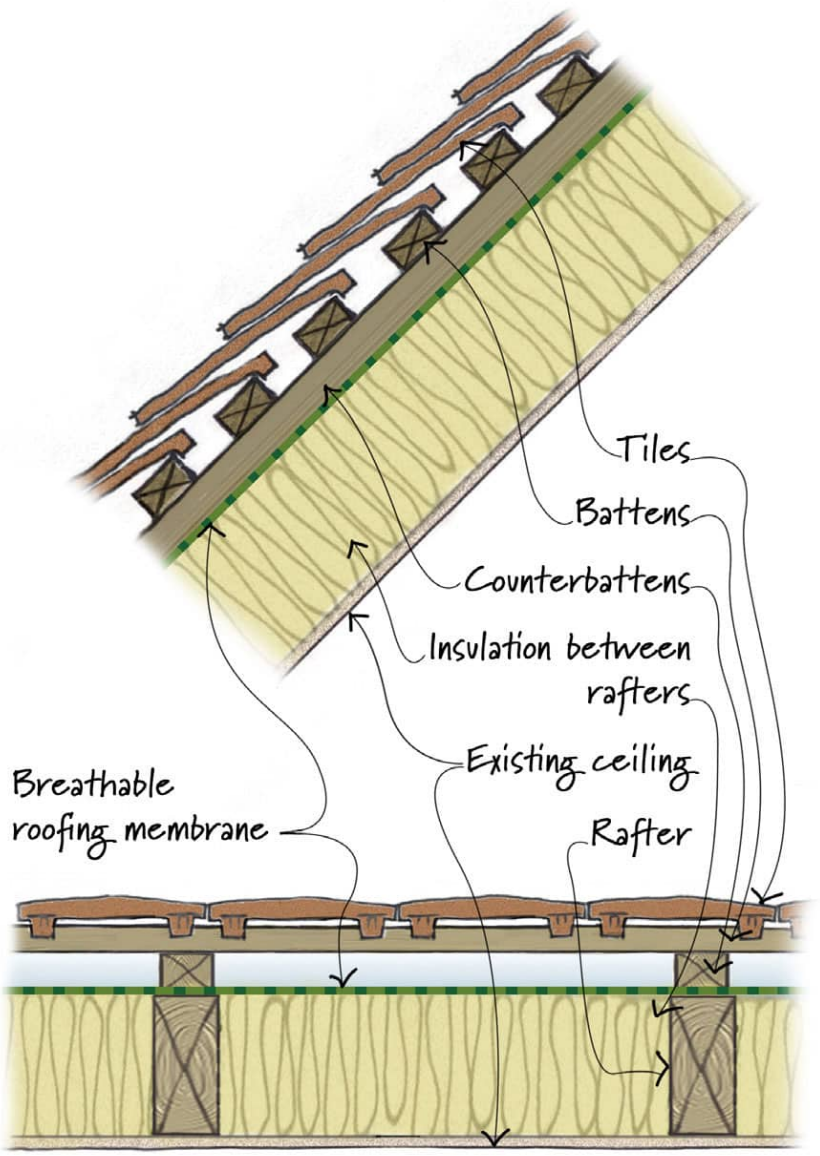
This roof was stripped ready for re-tiling, providing an opportunity to insulate from above. It is a semi-occupied roof space (See Semi-occupied roof, shown here) and the decision was taken to insulate between the rafters, over the area of sloping lath and plaster ceiling, and along the section of horizontal ceiling. This left an area of cold ventilated roof space above.

Wood fibre batts are easy to cut with a blunt saw.

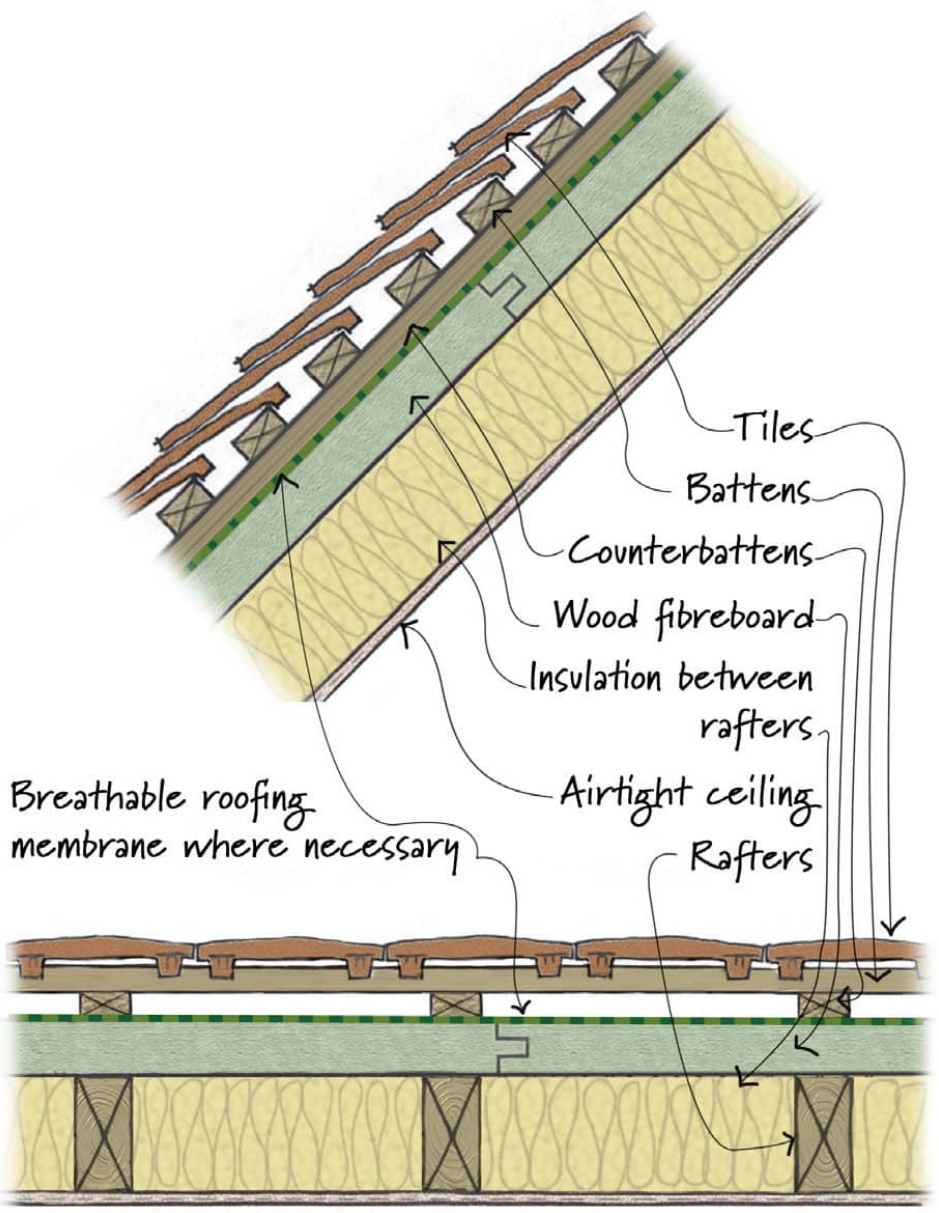
As the work progresses up the roof, the breathable roofing membrane is fitted with a counter-batten and batten over, all screwed rather than nailed to avoid damage to the sloping ceiling below.

The top of the insulation should be fitted flush with the upper surface of the rafter to avoid an unventilated void forming under the breathable roofing membrane.

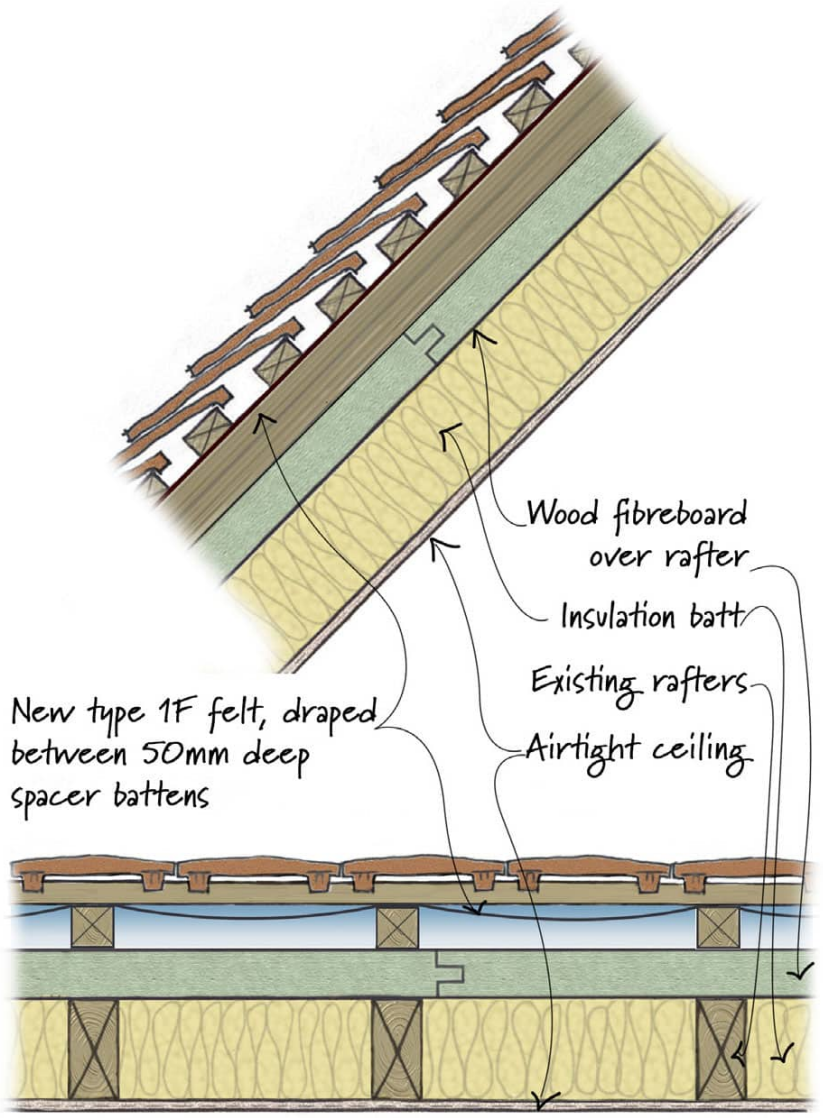
In another example, an airtightness membrane was used to form troughs between the rafters prior to the insulation batts being laid, and taped at all the junctions. While the technical justification for fitting the membrane is sound, in reality it is extremely difficult to fit neatly and can compromise the tightness of the insulation batts. In most situations it would be better to mend any cracks in the ceiling below the rafters, which can then serve as an airtightness layer without the need for the membrane.



Full-fill insulation batts fitted from above.



Wood fibreboard over rafters. Technically this is the best place for insulation but the roofline will be raised, affecting various external details.


Wood fibreboard over rafter
Insulation batt
Existing rafters
Airtight ceiling
New type 1F felt, draped between 50mm deep spacer battens

Type 1F felt can be used in conjunction with wood fibre sarking boards where bats are present. This provides a second line of defence where valleys and dormers are present.

Wood fibre sarking boards – over rafters

Wood fibre sarking boards laid over the top of rafters are technically an excellent means of achieving a breathable, insulated roof. This uninterrupted insulation layer means that the roof structure remains warm and is largely free from thermal bridges, minimising the risk of condensation. Sarking boards offer a practical alternative to breathable roofing membranes where bat activity is evident (See Bats and membranes, shown here). Their higher thermal mass achieves optimum decrement delay, protecting against overheating in attic rooms (See Decrement delay, shown

here). This detail also offers superior acoustic insulation for houses where traffic and other noise pollution is an issue.

This method of insulation does come with visual consequences. The thickness of the insulation will raise the level of the roof covering, typically by at least 40 mm plus the thickness of the counter-batten, changing the detail at the eaves and the verge. It will also raise the height of the ridge and therefore potentially pose problems, including the need for party-wall agreements on semi-detached and terraced houses, unless the adjoining roofs are similarly treated.

Always choose a wood fibre sarking board with an interlocking edge (See Wood fibre, shown here). This will achieve much better airtightness than a butted edge and will improve both thermal and acoustic insulation. It is also much easier to lay, especially when rafters are not exactly in the same plane. When used on roofs, the boards alone cannot achieve an adequate U-value so an insulation quilt or batt is added between the rafters.

Wood fibre sarking boards designed for over-rafter installation are water resistant, so they repel any moisture that breaches the tiles without the use of a membrane. For roofs with complex geometry, valleys and dormers, a compatible breathable roofing membrane can be laid directly over the sarking boards for extra protection, provided bats are not an issue. Where bats are present, type 1F bituminous felt can be overlaid, but this should be raised above the board to provide a ventilated gap, as in the diagram on the opposite page, top right.

This large roof was insulated with natural quilt between the rafters, and overlaid with wood fibre sarking boards.

The verge parapet detail to this roof would prevent the use of over-rafter sarking boards, as they would raise the roofline above the level of the parapet coping stone.

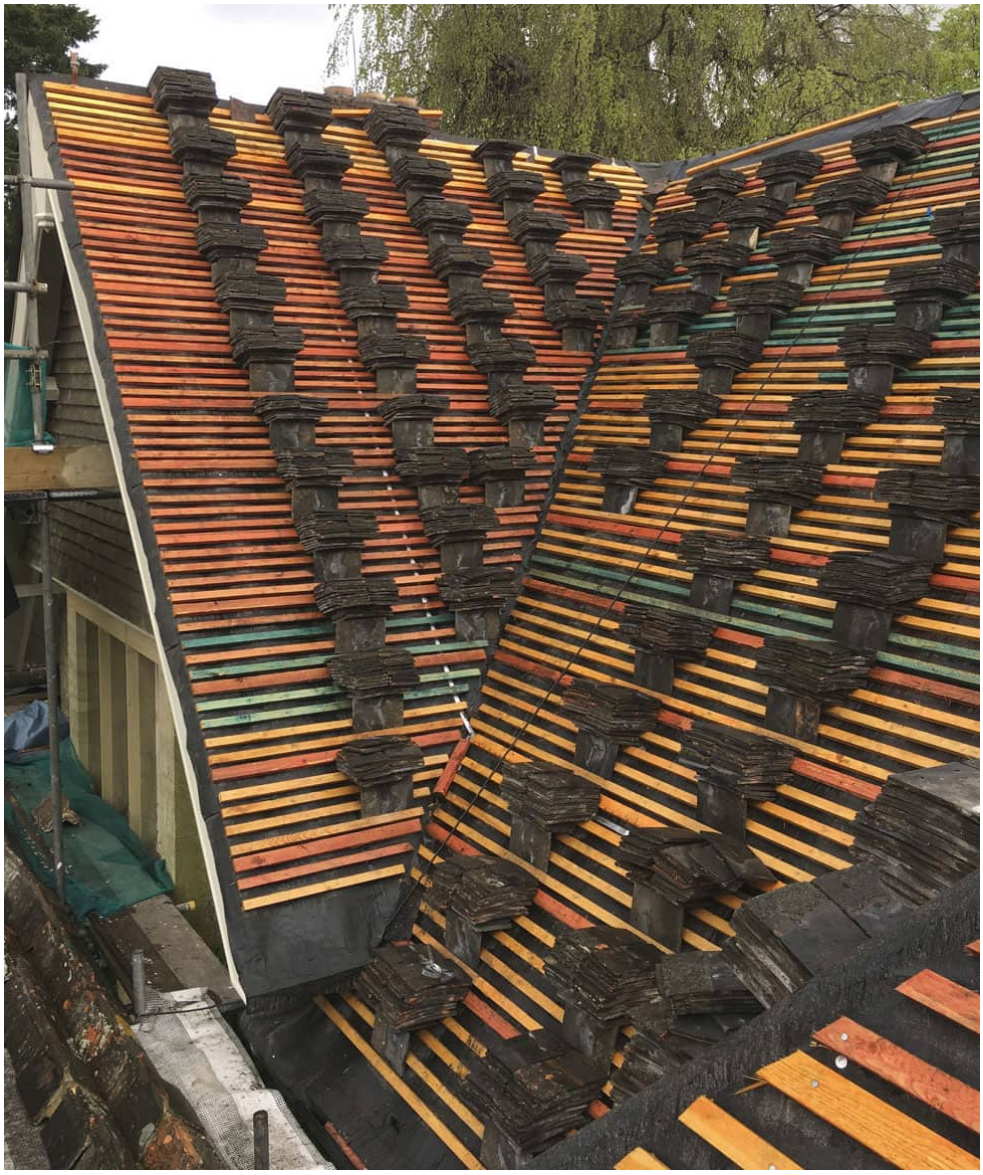
Multi-foils and insulating membranes

There are two principal multi-foil insulation products available for roofing. The first is designed as an insulation blanket. It typically combines thin layers of foam insulation and wadding, sandwiched between reflective foil layers and metallic film. The blanket can be fitted above or below the rafter and is secured with a counter-batten, but does not take the place of a roofing membrane, which is required in addition. The product is not breathable and, if used above the rafter, requires a vapour barrier to be fitted to the underside to avoid interstitial condensation.

The second type combines layers of insulation and reflective foils with a breathable roofing membrane, in a single product. It is commonly referred to as an insulating breather membrane. It is quick and easy to install and extremely popular with roofers. Insulating breather membranes may prove useful in specific situations, particularly where the roofline cannot be raised. In this instance, they can be draped between rafters, obviating the need for a counter-batten.

Uninformed roofers may try to persuade a client to use multi-foils or insulating breather membranes without additional insulation, but it is a false economy not to insulate further while the roof is open.

Where used, multi-foils must be installed exactly to the manufacturer's specification and particular attention needs to be paid to detailing. Both forms rely on being taped at all junctions to avoid draughts from breaching the insulation layer. This is difficult to achieve in practice, and only certain compatible tapes will provide the longevity required. Untaped junctions, or taped junctions that fail, will result in a draught passing through, allowing cool air to by-pass the insulation.



Over-rafter wood fibre sarking boards were used due to the presence of bats but, because of numerous valleys, type 1F felt was also laid as a second line of defence, as shown in the diagram on the opposite page, top right. The increase in the height of the roofline was disguised with deeper barge boards.

Correct installation is critical when using a multi-foil insulation.

An insulating breather membrane is fitted over an old roof. In this instance, the space between the rafters has been partially filled with additional wood fibre insulation batts.

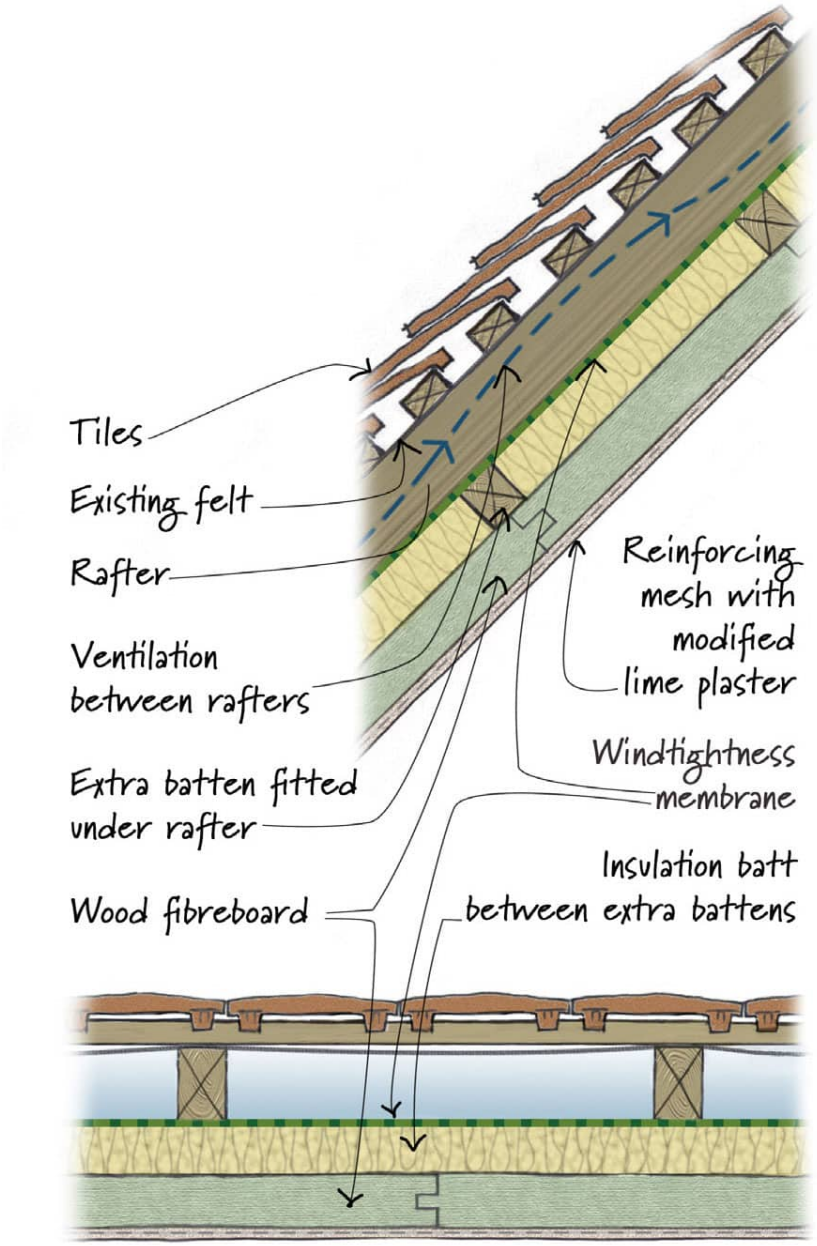
Multi-foil products have been popular in recent years, and may be useful on undulating roofs where a thin insulation solution is necessary. Careful specification and site supervision are essential to ensure the designed U-values are achieved.

Rafter-level insulation from below

Where insulation is being added to the underside of rafters without disturbing the tiles or slates, any solution should consider the following:

- What is the condition of the roof covering? Before attempting any insulation to the underside, replace broken tiles or slates and address all defects.
- Is there an old lath and lime plaster ceiling fixed to the underside of the rafters? If the condition is good, an alternative solution should normally be found that does not involve removing it.

- If you have a modern sloping ceiling, ascertain what it is made from. Is it modern plasterboard or fibreboard? If it is either of these, it should be relatively easy to take down and expose the rafters. If you have any concerns that it may be asbestos, it must be removed by a specialist firm.
- What condition are the rafters in? If they have been badly affected by beetle infestation, or have rotted, it is important to repair them before covering them up, especially if you are applying more load to them with the weight of the insulation. This can usually be done quite easily by fixing extra timbers to the side of the existing rafters.
- Is the roofing felt above the rafters non breathable? If so, additional ventilation may be required.
- Do you need to incorporate vents within the tile/slate covering to prevent condensation forming on the underside?
- Do you need acoustic insulation? If so, look for a higher-density product, such as wood fibreboard.



If the roof covering is sound and not due to be replaced for some years, wood fibreboard can be fixed under the rafters. It may be necessary to fix extra battens running horizontally to accommodate an additional layer of quilt, leaving the space between the rafters clear for ventilation. This is shown in the step by step photographic sequence on the opposite page.

Wood fibreboard – under rafters

For a relatively straight roof, wood fibreboard, combined with a breathable insulation quilt or batt, is an ideal solution. If properly installed, this provides acoustic, thermal and solar insulation. It is important to leave a

minimum of 30 mm ventilated cavity above the insulation to prevent condensation. This may be easily achieved by fixing extra battens under the rafters running at right angles. These should be the same depth as the proposed insulation quilt, which can be laid between them. The original rafters can then be left clear for ventilation.

This pantile roof in Norfolk does not need replacing so insulation may be best carried out from below.

Under rafter insulation

Step 1 The existing roof to this cottage consisted of thin-section oak rafters with 1970's impermeable, bituminous roofing felt over the top. The roof space was to be converted to a habitable room but, as the tiles above were sound, the insulation was added from below.

Step 2 Extra battens were fixed horizontally to the underside of the rafters, with the same width spacing as the insulation batt. Short lengths of wood were used to separate the laps in the roofing felt, to increase ventilation and reduce the condensation risk. Thermal efficiency could be improved further by stapling a windtightness membrane to the underside of the old rafters to reduce air circulation in the insulation.

Step 3 The insulation batt is placed to fit snugly between the extra battens.

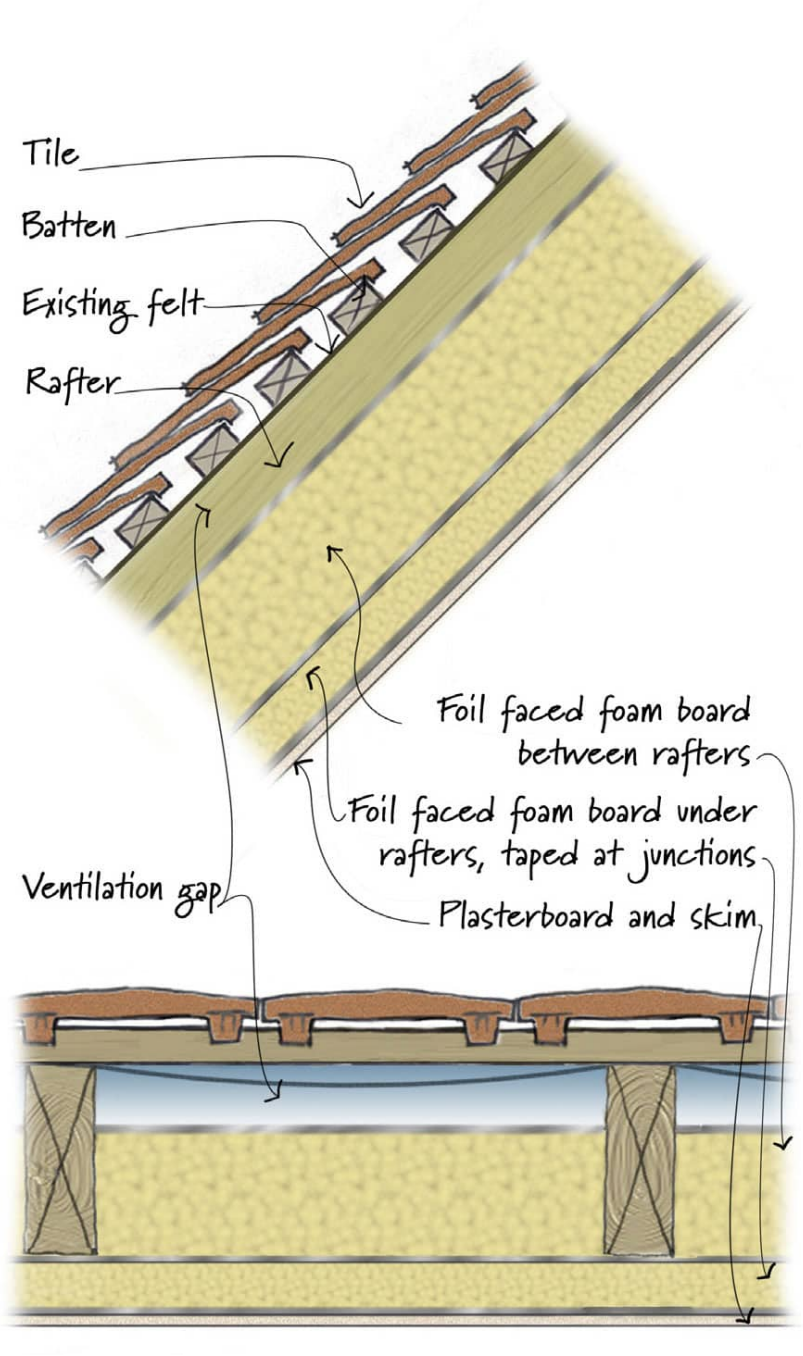
Step 4 Tongue-and-groove wood fibreboard is fitted over the top and taped at any butted junctions.

Step 5 The surface is skimmed with a base coat of modified lime plaster.

Step 6 The plaster is keyed with a metal comb.

Step 7 Fine plastic mesh is gently pushed into the plaster to prevent cracking, minimising water vapour passing through. Once dry, a lime setting coat is applied on top.

Step 8 The finished attic room. Note that the purlins have been left exposed as they are set below the rafter line, but these could potentially act as a thermal bridge.



Foam board between and under rafters.

Foil-faced foam board and plasterboard – under rafter

For a standard solution, which is familiar to most builders, modern foil-faced foam board can be fitted between the rafters. This can be problematic, as many old rafters are neither straight nor parallel. Even when the rafters are regular, it is extremely difficult to fit rigid foam board without leaving

gaps at the side that negate the value of the insulation. In addition, water vapour passes up through the gaps into the cold void above and condenses on the underside of the felt or tiles. This in turn drips onto the top of the foam board and runs down into the eaves. Expanding foam is sometimes used to fill the gaps, but this is extremely difficult to achieve in practice and tends to crack as the roof flexes.

A further sheet of foam board can be fixed under the rafters and is taped at the junctions to minimise moisture vapour passing through. This is finished with foil-backed plasterboard and skim.

Using foil-faced foam board in this situation is fraught with technical and practical difficulties, achieves poor acoustic insulation and does not protect against solar gain – an important consideration when the room is occupied. In most instances, an alternative detail using wood fibre batts and sarking boards will provide better performance on all fronts, at a similar cost. When using foam board, bear in mind that:

- The rafter line needs to be relatively straight for this option, as the boards cannot flex to fit.
- The thickness of the boards used between the rafters will depend on their depth – remember to leave a 50 mm gap between the top of the insulation and the underside of the felt. If the foam board fitted to the underside of the rafters is more than 50 mm, it may be difficult to fix the plasterboard because of the length of fixings required.
- Where foam board is only fitted between rafters – and not to the underside as well – a separate vapour barrier will need to be installed to provide airtightness.

This roof is being fitted with foam board between the rafters. Such insulation can also be added from below, but care should always be taken to minimise gaps and prevent condensation.

Spray foam insulation

Unfortunately, the practice of spraying foam on the underside of a roof has for many years been offered as a perfect solution for old buildings. The technique uses expanding foam, sprayed between the rafters, either to the underside of the roofing felt or directly to the tiles or slates. It is advertised as a quick, cheap and easy solution to repair leaking and failing roofs.

In reality, it forms a very short stopgap and will almost certainly cause problems in the longer term. The foam covers parts of the rafters, potentially trapping dampness and causing their moisture content to rise, making them susceptible to beetle attack and decay. In addition, it inhibits any future internal inspection of the roof for maintenance purposes and complicates minor repairs. Importantly, where spray foam is stuck to the underside of tiles or slates, in most instances it prevents them from being reused, where normally a large proportion would be salvageable. This adds considerable expense when the roof is next re-tiled.

This roof had spray foam applied to the underside of the old Welsh slates. Not a single slate could be reused, adding considerably to the cost of the new roof.

Spray foams may seem like a good solution, but are usually a false economy in the longer term.

INSULATING DORMER WINDOWS

Dormer windows are notoriously difficult to insulate and are a common cause of thermal bridging in roofs. The ‘cheeks’ or triangular side walls to dormers are usually very thin. If they are built of timber studs, they will contain a cavity, often no more than 50 mm. The rafters are also generally thin-section as they carry a limited load. Such narrow cavities minimise the opportunity for insulation, so using an insulation material with a high thermal value, such as foam board or aerogel, may be a good option. Be sure to get the insulation right into the corners, leaving no air voids.

When this old roof was stripped and the modern window removed, the thin walls to the dormer structure were revealed. Insulation needs to be carefully detailed to avoid spoiling the historic proportions.

Thatched roofs can provide excellent insulation.

THATCH AND INSULATION

Until recently, it was assumed that thatched roofs are, in themselves, excellent insulators and require no additional measures to improve their energy efficiency. While this remains largely true, certain roofs perform considerably worse than others.

The thermal performance of thatch is dependent on a number of variables:

- Thickness: long straw and combed wheat reed are generally built up in layers over many centuries and are often up to 1 m thick. Conversely, water reed is stripped to the rafters and applied in a single 300 mm coat.
- Pitch: a steeper roof will shed water more quickly and retain less moisture. The drier the thatch, the better insulator it will be.
- Condition: a well-maintained thatch will perform better than one in poor condition. If not maintained, abutment details such as those around chimney stacks and dormers can let in draughts, while vermin and bird holes also reduce thermal efficiency.

Recent tests have established that 300 mm water reed can achieve an average U-value of 0.29 W/m2K and 300 mm long straw approximately 0.23 W/m2K. Combed wheat reed falls somewhere between these two figures. As the latter two types are often laid in much thicker layers, their U-value is likely to meet, or come close to, building regulations.

The main problem in terms of thermal performance is air infiltration at junctions and abutments (such as around chimney stacks) and particularly at the eaves, where draughts are commonplace.

If thatched roof spaces are not occupied (cold roof), the best solution is to insulate the flat ceilings to the rooms below as already described. To maximise the life of the thatch, encourage ventilation to the underside by clearing the eaves and getting a good through draught.

Three-hundred-year-old clay plaster applied directly to the underside of the original basecoat of thatch. A rare survival, it has a beautiful texture and was carefully repaired when the house was brought back into use. Note the pole rafters, probably in softwood, which are particularly vulnerable to decay if exposed to dampness for a prolonged period.

If the roof space is occupied (warm roof), an airtightness test or thermal imaging (See Airtightness test, shown here; See Thermal imaging, shown here) will quickly establish any problematic areas. Vapour-permeable materials, such as lime mortar and tightly compacted natural quilts, can be used to plug draughts. These will wick water away rather than hold it against the thatch. It is important not to use impermeable materials, such as expanding spray foam, next to thatch, as these will trap moisture at the interface and accelerate decay.

When applying a ceiling to the sloping underside of a thatched roof, it is important to use a breathable solution, particularly where draughts have been minimised and ventilation to the underside no longer exists. If historic smoke-blackened thatch is present, a different solution would have to be considered so that this important feature is not lost. Given the complexities and costs of thatching, always consult a specialist if altering traditional details.

FLAT ROOFS

Flat roofs were traditionally formed of joists overlaid with what are essentially plain-edged floorboards with small gaps between to accommodate seasonal movement and aid ventilation. Over this deck, lead, copper, zinc and other metals were commonly laid.

Modern flat roofs, or old roofs that have been repaired or upgraded, are likely to have a deck of wooden sheet material, such as chipboard or ply, and might incorporate an underlay. This may be covered with traditional materials, mastic asphalt or more recently developed roofing products such as synthetic membranes. Internally there is likely to be a ceiling, either of plasterboard or lath and plaster.

Two points must be remembered: flat roofs should never be totally flat, as they need to shed water, and the materials used on them must allow for contraction and expansion due to temperature changes.

Roof lights can form a thermal bridge if not properly insulated.

Adding insulation

There are a variety of ways of insulating a flat roof. The main concern is ensuring that condensation does not form within the roof structure. The insulation may be:

- Fitted beneath the roof structure just above the ceiling, leaving the structure ventilated and colder than the room below to create a ‘cold deck’.
- Installed above the roof structure but beneath the waterproof covering, maintaining the temperature of the structure close to that of the room below to form a ‘warm deck’.
- Laid above the waterproof covering, but beneath a protective layer such as screed, soil or pebbles as an ‘inverted deck’.
- Fixed within the living space below the ceiling.

Gaining access to install insulation in flat roofs is generally difficult, except when either the roof covering or the ceiling below is being renewed. Not all flat roofs are deep enough to accommodate the thickness of insulation

required along with sufficient ventilation space, so it will be necessary either to compromise on the level of insulation provided or to deepen the overall build-up of the roof. This can present aesthetic and practical difficulties and is especially problematic where pitched and other roofs run into the flat roof. In all cases, it is essential that the roof has a sufficient fall to ensure water is shed and that any flashing around its perimeter is of sufficient depth to be effective.

06 | WINDOWS AND DOORS

Few building elements have a greater visual impact than windows and doors. Sadly, they are frequently the first items to be replaced, often in the name of energy efficiency. Time and again, this work is ill-conceived and unnecessary, with the results devaluing the building and destroying the special qualities that set it apart.

Draughty old windows and doors need not be a fact of life; sensitive repair and retrofit can be straightforward and hugely effective in improving their thermal and acoustic performance. These simple measures are a good investment and will help achieve energy savings while causing the minimum loss of historic character, helping to protect the value of your house over the longer term.

Conversely, replacing windows and doors has high monetary, aesthetic and environmental costs. Original windows and doors contribute much to the historic integrity of a building and, in many cases, are important in maintaining the look and unity of a whole street. It is worth remembering that, historically, the timber used in joinery was invariably slow grown, more durable and of far better quality than is generally available today.

Just as important is original glass. Old handmade glass has ripples, air bubbles and other manufacturing imperfections that add sparkle and character to the face of a building. In comparison, modern machine-made glass is flat and lifeless. The replacement of a window or door also means the potential loss of the latches and other fittings.

OLD WINDOWS CAN BE EFFICIENT

Cold single glazing and draughts around the edges of sashes and casements lead to temperature asymmetries in the vicinity of windows. To keep warm and avoid losing body heat, there is a tendency to move away from

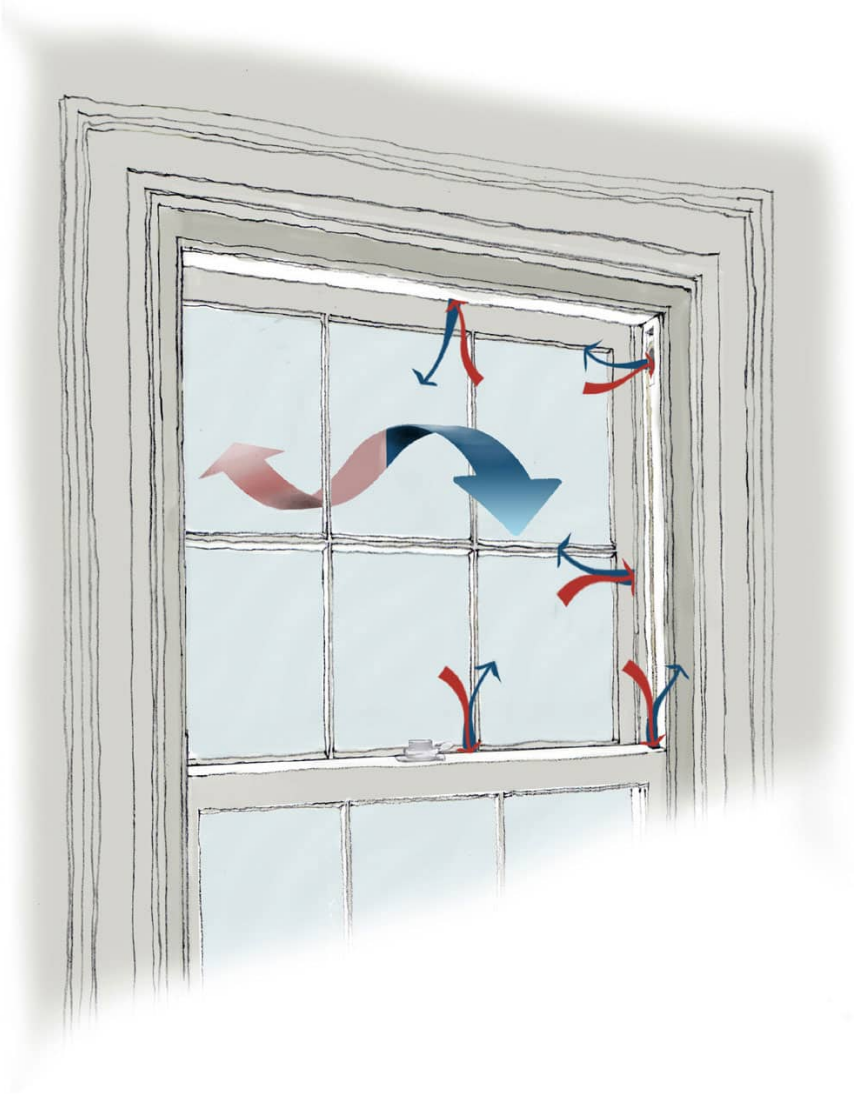
windows in chilly weather, effectively reducing the usable space within the room.

Original doors and windows give old buildings charm and character and are valuable assets that are worth retaining.

It is important to understand that the thermal performance of windows is affected by two independent factors: conduction through the glass and draughts around the frame. Even a well insulated window can still lose heat if the edges are not draughtproofed.

In terms of thermal conduction, testing has revealed that a typical old window has an overall U-value of between 4.4 and 4.8 W/m2K. The exact figure depends on the style of the window and the proportion of glass to wood. When we compare this to the U-value targets in the 2010 Building Regulations, stating that a window must meet 2.0 W/m2K, we can immediately see the inefficiency of single glazing. A typical double-glazed window has a U-value of 1.9 W/m2K.

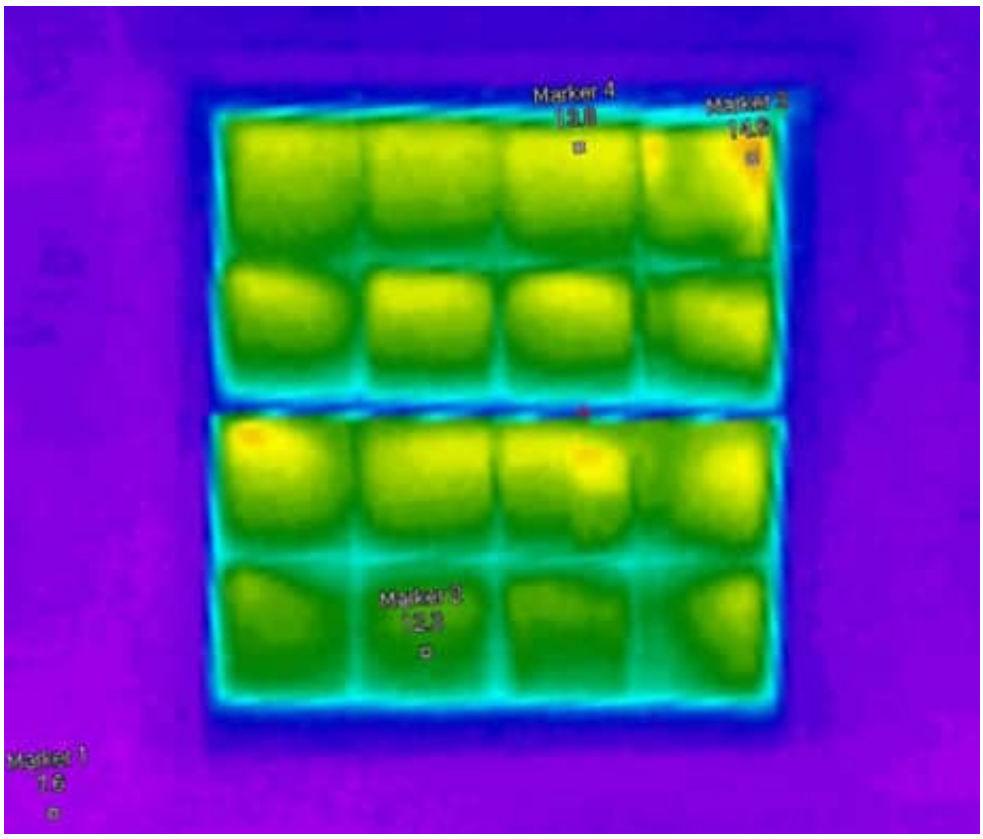
Doors and windows are the face of a building, but are potentially a major source of heat loss.



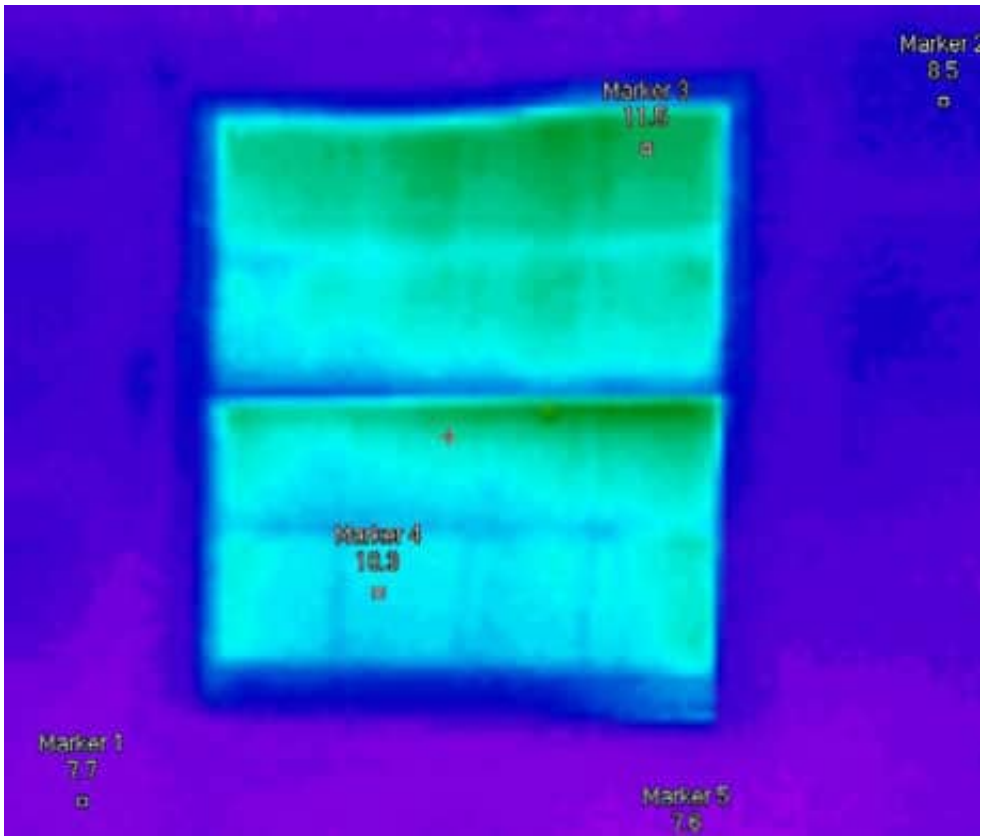
The thermal performance of windows is affected by both thermal conduction through the glass and draughts around the frame. These potentially occur at all edges of both casement and sash windows, but sashes tend to have more gaps and heat is also lost through the sash pulleys.

This does not mean that old windows must be replaced. Research has proven that, with care and sensitive intervention, traditional windows can perform better than double glazing. The research looked at various options for reducing heat loss through a traditional sash window, without resorting to replacement. The results overwhelmingly showed how simple measures can improve the energy efficiency of old windows and bring them into line with current U-value requirements. These measures also create more even

temperatures within a room and provide acoustic improvements by cutting traffic and other noise from outside.



Thermal images of an old sash window before (above) and after secondary glazing was added (below).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8.5
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7.6

U-value test results

Glasgow Caledonian University carried out a series of ‘hot box’ tests on an old sash window that had been repaired. First they established the U-value of the window in its existing form; then they calculated the improved thermal efficiency following a variety of simple measures.

	WHOLE WINDOW U-VALUE	HEAT LOSS REDUCTION
Victorian sash window, 2 over 2 panes	4.3	–
Heavy curtains	2.5	42%
Traditional, well-fitting shutters	1.7	60%
Plain roller blind	2.7	37%
Reflective roller blind	1.9	56%
Insulated honeycomb blind	2.1	51%
Low-E secondary glazing	1.8	58%
Low-E secondary glazing and shutters	1.6	63%

Heat flux monitor measuring the U-value of a single-glazed window pane.

These early nineteenth-century windows in Oxfordshire were carefully repaired and draughtproofed.

REPAIR OR REPLACE?

Owners of old houses are constantly under pressure to upgrade draughty windows and doors. Targeted marketing from window renewal companies frequently promises instant energy efficiency, maintenance-free plastics and cost-saving special offers. Unsurprisingly, many people have been seduced by the ‘quick fix’ of PVCu – polyvinyl chloride un-plasticised, also known as uPVC.

At their worst, these plastic windows look heavy and out of proportion, but manufacturers are now producing ranges of plastic mouldings far more akin to their wooden forebears. So is there ever a case for replacing traditional windows with good-quality PVCu lookalikes?

A product of the petrochemical industry, PVCu is a material that is toxic and energy-hungry in its production and non-biodegradable when scrapped. Despite the availability of recycling schemes, recycling is generally difficult and these windows frequently end up in landfill. Sadly, plastic windows have often replaced perfectly good wooden windows that could easily have

been overhauled and upgraded to make them considerably more energy efficient.

In the eighteenth and nineteenth centuries, Baltic pine was imported to make many of the windows that survive today. This was slow grown, straight grained and particularly durable. It is not uncommon to find wooden windows that are 100, 200 or even 300 years old and still in excellent condition. If they are damaged, a good local joiner or one of the many companies that specialise in this work should be able to make relatively inexpensive repairs. In contrast, a damaged plastic window is usually unrepairable and the whole unit has to be replaced.

A reputable firm can make a high-quality wood window from sustainably sourced timber and, increasingly, modified timber is being used due to its exceptional dimensional stability and durability. High-performance timber windows need be no more expensive than their PVCu equivalents: research into lifetime costs has shown that wood windows work out 2–7 per cent cheaper than PVCu.

BUILDING REGULATIONS

Under the Building Regulations, windows and doors within their frames are referred to as ‘controlled fittings’. Where it is proposed to replace the complete window and frame or door assembly in an existing building, the replacements should comply with current U-values under the circumstances listed shown heere. More specifically, replacing a door leaf or the opening casement or sash of a window while retaining the existing frame does not constitute a material alteration: the new part should be at least no worse than the original in terms of Part L. It is, of course, advisable to introduce such measures as can be reasonably applied, such as draughtproofing and seals, where this does not detract from the building’s appearance or character.

The Building Regulations recognise the need to protect traditional and historic facades to old buildings, and therefore may accept a lower centre-pane U-value for individual replacement windows that need to match existing ones. They may also accept single glazing supplemented with low emissivity secondary glazing.

Ventilation

When replacing windows or draughtproofing to improve their airtightness, adequate room ventilation must be maintained, especially where combustion appliances are present. Trickle vents cut into the top of the frame are a standard way of introducing such ventilation, but they detract from the appearance of a window. It is worth exploring the possibility of introducing ventilation by other means (for example, air bricks with sliding covers, venting directly into the room, may be visually preferable), but check this is acceptable with your building control officer. If commissioning bespoke windows and trickle vents are not required, make this clear at the time of ordering.

FIRST THINGS FIRST

There are numerous ways of upgrading old windows that are often cheaper and more energy efficient than wholesale replacement. Before doing anything, ask yourself these questions so that you can make an informed choice on treatment:

How frequently does the window get opened?

For instance, a window on a roadside elevation may remain permanently closed. If this is the case, a single panel of glass or plastic secondary glazing, discreetly fixed with magnetic strips so that it can be lifted out for cleaning, may be the ideal option.

Do you open the window in the warmer months but keep it closed in winter?

Many windows will come into this category. If so, temporary, fixed-panel magnetic secondary glazing, which is easy to put up in the winter but can be taken down and stored in the spring, could be the perfect solution.

Preserving value

Windows are recognised as being valuable assets. A survey by Historic England revealed that 82 per cent of estate agents felt that original features, such as sash windows, tend to add financial value to properties, while 78 per cent believed they help sell a property more quickly. Whereas replacement PVCu windows were once regarded as a selling point in estate agents' particulars, in many instances they are now more likely to put off a potential buyer.

The fine detailing of the original sashes of the centre bay window contrast with the poorly executed replacements on either side. The loss of the arched window heads, and other details, devalue the entire terrace.

Do you open the window on a regular basis throughout the year?
Bathroom windows, in particular, come into this category. Carefully considered and properly installed extractor fans can reduce the need to open windows in steamy rooms. Where windows do need to be opened regularly, either draughtproofing or an opening secondary-glazed unit is likely to be the best option.

Are you looking for good acoustic performance from your window?

Houses under a flight path or near a busy road will need special consideration to minimise noise pollution. Secondary glazing is particularly successful in this instance, and performs far better than double glazing.

Does the window form part of an emergency escape route?
If so, secondary glazing is usually unsuitable as it will increase the time required to open the window and may restrict the size of the opening. Draughtproofing may be one solution.

CURTAINS, BLINDS AND SHUTTERS

Before tackling the windows themselves, think about the other options available. Curtains and shutters have long been used to reduce both heat loss and heat gain and it is worth considering ways of improving their thermal performance.

Controlled ventilation may be achieved simply by opening windows.

Heavy curtains

A heavy curtain is a simple means of cutting draughts and reducing heat loss through a single-glazed window, especially if it has an insulated lining.

There are a number of things to consider if designing a curtain for this purpose:

- Fit the curtain from floor to ceiling where possible, otherwise the cool air between the curtain and the glass will flow out of the bottom and create a draught.
- Hem the curtains in situ and make sure they are touching the floor. Even a small gap of a few millimetres at the base of the curtains will allow the leakage of cool air.
- While it is not appropriate for every window, a pelmet to the top of the curtain helps to close off draughts and stop warm air from disappearing down the back.
- If you have a radiator under a window that cannot be relocated, fit a shelf above the radiator for the curtain to sit on. This prevents warm air from rising behind the curtain and disappearing through the window.
- Set the curtain pole or rail as close to the wall as possible. This is often difficult to achieve, as brackets are frequently designed to set the pole proud of the wall, in which case they may need to be adapted. A big gap at the top or the side will dramatically reduce the benefit of the curtains. Alternatively, close the gap with a board down the side of the window, designed to appear as part of the frame. These measures will all help create an ‘airlock’ between curtain and window.
- The curtains should be lined with an insulating lining and interlined with heavy fleece; both are available as standard from curtain manufacturers and high-street stores.
- Bear in mind that these curtains are heavier than normal, so any curtain track or pole should be fitted with this in mind.

Blinds fitted within the window reveal are particularly effective.

Thermal blinds

Blinds are often more successful than curtains at reducing heat loss, especially if they are fitted within a window reveal close to the window. Thermal blinds incorporate a variety of insulating and reflective layers designed to minimise conduction through the fabric. These may be fitted to create a ‘seal’ around the edge of the blind, usually by screwing a lightweight metal runner to the window frame. Some systems incorporate magnets that hold the blind against the frame. Always discuss your

particular window with the blind manufacturer to check compatibility before ordering.

Hanging heavy insulated curtains will significantly reduce heat loss.

Well-fitting shutters are a good way of retaining heat at night.

Conservation shutters have glazed rather than solid panels, so they can be kept shut while allowing daylight in.

Shutters

Wood is a good insulator so, as long as they are well fitted, wooden shutters dramatically reduce heat loss. Consider overhauling existing shutters, provided there will not be an unacceptable level of alteration and loss of historic character. They must fit tightly, meeting with a rebated edge rather than a square butt joint, ideally with some sort of brush strip or rubber seal.

The disadvantage of standard shutters is that they only work at night so do not assist with energy efficiency during daylight hours when the shutters are open. Where your window reveal is splayed or designed to take a shutter but the original is missing, a ‘conservation’ shutter may be a solution. This

is a bespoke piece of joinery that contains a double-glazed unit within a frame, rather than a wooden panel. It can be permanently closed in the winter months, allowing daylight to pass through while keeping out draughts, and folded back out of the way in the warmer months when the window is regularly opened.

TOP TIP: TRAPPING SOLAR GAIN

Close shutters, blinds and curtains at dusk in the winter months to trap solar gain accumulated during the day.

DRAUGHTPROOFING

For windows to be as thermally efficient as possible, they must be properly maintained. Specialist companies will overhaul windows, removing excess paint, cutting out rotten wood, releasing stiff windows, replacing sash cords, balancing weights, easing latches and catches and fitting new beading. At the same time, they will fully draughtproof the window.

Professional draughtproofing involves cutting a rebate around the edge of sashes or casements.

A brush strip is fitted into the rebate after the edge of the sash has been primed.

A simple leather strip, fixed to the window frame with copper nails, is an early solution to draughtproofing.

Draughtproofing reduces the gap between the window casement or sash and the frame, but it is only part of the solution when upgrading the thermal efficiency of old windows. While it deals with heat loss via draughts, it does not address thermal conduction through the glass itself. Carefully executed, draughtproofing is an ideal solution where a window is regularly opened, and is virtually invisible when the window is closed.

Selecting the right seal

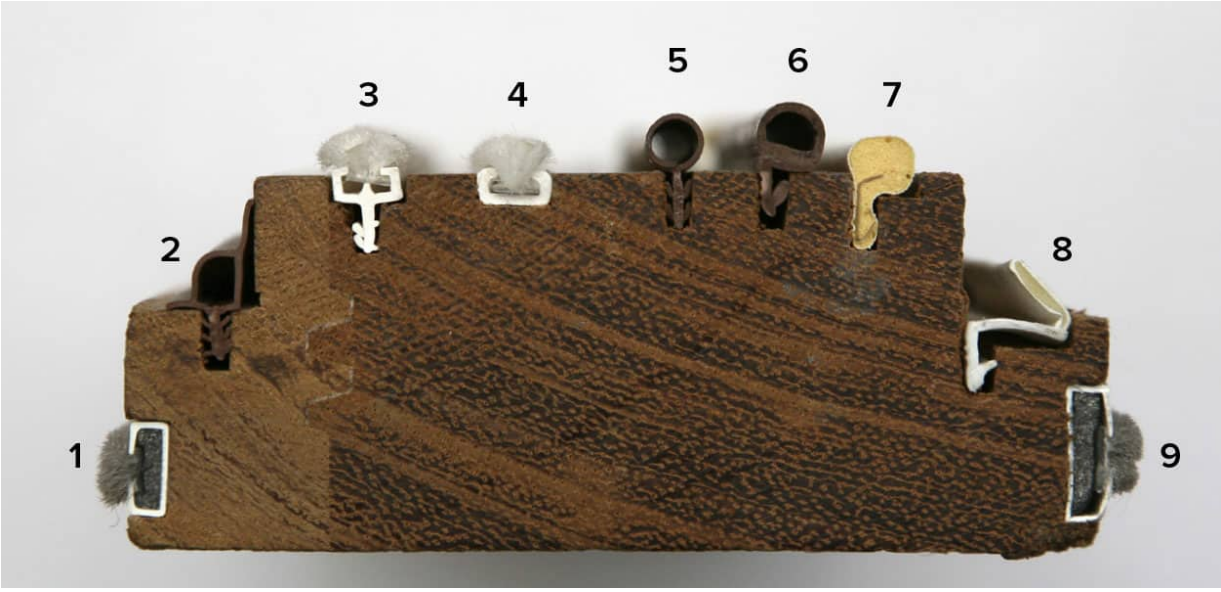
There are two main types of draughtproofing seals: compression seals and wiper seals. Specialist draughtproofing companies tend to carry a standard product and joiners may have a preferred choice of seal, but there are many

products on the market that are worth researching. Speak to a variety of manufacturers; most have a technical adviser to answer specific queries. Ask for a sample before placing a large order to check its quality and compatibility with your situation.

Compression seals are designed for use on hinged windows where the casement closes against the frame and the seal compresses to fill the gap. They come in various forms, usually made from EDPM (ethylene propylene diene monomer) rubber or silicone, or are made of foam, coated in a tough polyethylene skin that sheds any paint that comes into contact with it.

Wiper seals are generally used in sliding applications – for instance, on the meeting rails of sash windows where the upper sash slides across the lower sash. These are usually a brush pile, held in a plastic carrier and rebated into position.

Brush pile seals can also be used as compression seals, but they tend to lose their springiness over time, squashing down and failing to fill the gap.



Samples of various draughtproofing products.

1, 4, 9: Different colours and sizes of brush pile seals in self-adhesive pile carrier.
2: Bubble compression seal for internal corners of frames.
3: Brush pile seal in push-fit pile carrier.
5, 6: Small and large push-fit bubble seals.
7: Foam or cushion compression seal with polyethylene skin.

8: ‘V’-section push-fit compression or spring seal.

Staff bead and parting beads are available with brush pile seals pre-fitted.

Draughtproofing in progress: a parting bead is tried for size.

Stick-on solutions

Surface-mounted self-adhesive draughtproofing strips tend to fail fairly quickly. Even where the adhesive is strong, the painted surface onto which they are glued is often lumpy or flaky, so a good bond is rarely achieved. Certain rubber compression seals become slightly sticky in warm weather,

so they adhere to the face of the door or window and get pulled off the frame on which they are mounted. This is particularly problematic on south-facing elevations. While surface-mounted strips are always better than nothing, for a long-lasting solution choose seals that are either fixed with pins or screws, or rebated into position.

The edges of window frames must be taped to achieve airtightnesss.

Draughtproofing checklist

When you are employing specialists to overhaul and draughtproof windows, check that the firm is reputable and the joiners are experienced:

- Ask about the quality of the brush strips/compression seals and request a sample – some cheaper versions will compress and quickly lose their shape, failing to exclude draughts after a short time.
- Seals and brush strips are usually available in white, black and brown, so choose the best match for your window.
- If you are painting windows, avoid getting paint on the draughtproofing seals as this may stop them from working effectively.

- On sash windows, ensure any replacement staff and parting beads are wood and not plastic.
- Draughtproofing companies will often plane the edges of sashes or casements to help them run more smoothly. Ensure that these edges are painted with at least a priming coat before they are put back in the frames, otherwise they will swell and jam. Most firms do not allocate time to allow primers to dry and therefore do not bother – ask about this in advance.
- When the window is re-assembled, ensure that the window furniture is working correctly so that it can be closed tightly.
- If you are replacing sash fasteners, choose a good-quality cam-action fastener. These pull the meeting rails together, creating a more airtight junction.
- A properly draughtproofed window should open and close smoothly. If it rattles, it is likely to have gaps and draughts.

Draughtproofing sash pulleys

One disadvantage of draughtproofing sash windows is that the standard techniques do not address the sash pulleys. These can be responsible for significant draughts, particularly on a windy day.

A number of products are available to reduce draughts through sash pulleys, although it is worth checking that they will fit your pulleys. These are either fitted behind the pulley or, in some cases, on the face of the pulley. With old windows, the hidden solution is preferable and involves removing the pulley. The plastic draughtproof cover clips to the pulley and completely encloses it, insulating against draughts with a combination of polyurethane foam and a brush seal around the sash cord's exit.

A sash pulley slotted into a draughtproof cover.

Draughtproofing the frame

Gaps between window and door frames and the wall into which they are inserted are a frequent source of air leakage, both with existing frames and when new ones are installed.

A number of measures may be required to ensure proper draughtproofing. In all cases, the frame should fit as tightly and securely as possible within the masonry or framing of the wall. Spray foams and expanding compression tapes are good at insulating the gap but, for airtightness, tape should be used internally around the edges of the frame. Externally, burnt

sand mastic offers a suitably flexible finish (See Polyurethane (PU) spray foam, shown here; See Tapes and primers, shown here; See Burnt sand mastic, shown here).

SECONDARY GLAZING

Secondary glazing involves adding supplementary glazing on the inside of the existing window. It comes in a variety of forms, either in glass or plastic, and is a good option for draughty windows. When carefully designed it is discreet and almost invisible, especially from outside, with the added benefit that it is totally reversible if the decision is taken to remove it in the future.

The big advantage of secondary glazing over draughtproofing is that it sits over both the frame and the glass. This not only reduces heat loss via thermal conduction through the glass, but also dramatically improves airtightness around the edges of the window. This can make a great difference to the U-value of a single-glazed window. A well-fitted secondary system is also acoustically superior to double glazing and can easily cut noise transmission through the window by over 50 per cent – a great bonus if you live on a busy road or under a flight path.

Draughtproofing metal windows

Modern metal windows, usually post-1965, tend to have weatherstrips set in preformed grooves. Older metal windows pose a particular problem when it comes to draughtproofing, as seals cannot be set into the frame or mechanically fixed, but gaps can be minimised with the careful application of silicone, preferably after redecoration. The basic technique is:

- Open the window.
- Ensure surfaces are clean, dry and free from flaking paint, rust and dust.
- Apply a release agent, such as plastic cling film or low-tack tape, to the edges of the window casement where it touches the frame when closed.
- Using a mastic gun, apply a bead of silicone to the closing edge of the frame – use either a matching colour or clear silicone.
- Close the windows immediately after applying the silicone – this will cause it to squeeze out and be moulded to the shape of the gap.
- Allow 48 hours for it to cure. Do not open the window during this time.
- Once dry, open the window and remove the release agent. The silicone should be adhered to the frame rather than the opening window.
- Trim back the silicone with a sharp knife to produce a tidy finish.

Arts and Crafts metal window.

Leaded lights tend to be draughty due to their poor fit.

Ensure that secondary glazing will not interfere with traditional shutters.

Ideally, the air space between the window glazing and the secondary glazing should be 16–20 mm. This prevents convection currents that lead to heat loss from developing within the cavity, but it is often not feasible. Thermal bridging is another consideration. Not all secondary-glazed panels are thermally broken so, in order to achieve maximum performance, a narrow strip of aerogel blanket may be fitted between the frame of the secondary glazing unit and the window (See Mineral materials, shown here).

Windows with working shutters sometimes pose challenges, as there may be insufficient room to install a secondary glazing unit, so it is important to check whether this will be an issue.

Most proprietary secondary glazing units are contained within an aluminium frame. Alternatively, a bespoke timber unit could be made by a joiner, but this tends to be more bulky. The timber must be dimensionally stable to avoid warping, as this will lead to draughts and condensation, so a modified wood product is likely to be the best material choice.

When specifying secondary glazing, ensure that any solid vertical or horizontal elements are as slim as possible and line up precisely with the meeting rails or mullions of the original window, making them unobtrusive and keeping sightlines clear.

Unless the secondary glazing is totally airtight, the original window should not be draughtproofed. Draughts from outside help ventilate the space between the window and the secondary glazing, dispersing condensation from within the void.

Secondary glazing must be carefully planned so discuss the pros and cons of any system with the supplier or installer and see samples of the profiles and materials proposed. Consider not only the thermal and acoustic performance of the secondary glazing but also its ease of use, aesthetics and long-term maintenance. Whatever system you choose, a means of cleaning the inside face of the secondary glazing panel, as well as the original window and the void between the window and the panel, is essential.

Secondary glazing – glass

Glass secondary glazing, usually within aluminium frames, is suitable for most window styles and is available in a number of forms. These include horizontal sliders, vertical sliders designed specifically for sash windows, hinged casements and magnetic lift-out panels for non-opening windows. Bespoke designs tailored to fit out-of-square windows can also be commissioned.

The system you choose will depend on whether you need to regularly open the window as well as on aesthetic considerations. Most types of glass

secondary glazing have a subframe that is screw-fixed and mastic-sealed to the window frame. When an openable unit is needed, this subframe can be quite cumbersome. For a non-openable window, the subframe of magnetic lift-out panels is far more slender and discreet.

Hinged casement secondary glazing with a lockable handle.

Sliding glass secondary glazing in closed (above) and open (below) positions.

A magnetic lift-out panel with toughened glass, installed on the road side of the room to reduce traffic noise.

The same panel being lifted out.

Openable secondary glazing units for sash windows slide vertically, aiming to mimic the way a sash works. They can be difficult and heavy to slide, especially on large windows, as they do not generally incorporate a pulley. Their profiles may be bulky, making them visually unacceptable. Unlike the original sash design, where both top and bottom sashes may be opened to maximise the circulation of air, the ‘sashes’ of secondary glazing can often only be opened at either the top or the bottom. For low sash windows that

are a safety issue for small children, having a top sliding secondary glazed system is essential.

Hinged casement secondary glazed units are an alternative to sliding units. Opening into the room, some offer tilt and turn and restrictor catch options to allow secure ventilation. They provide good access to the window and a means of escape. These systems tend to have more substantial frames than other secondary glazing and a handle that is not always in keeping with a period interior, although they are often lockable.

Most companies supplying secondary glazing will powder coat the aluminium frames to match your internal paint scheme. If you are opting for a colour other than white, make sure that the rubber seal where the glass meets the aluminium trim is also colour matched. Generally, the glass is laminated or toughened; this is essential for low windows. For maximum thermal performance, low emissivity glass should be specified (See Low-E glass, shown here).

Leaded lights

Leaded lights can be notoriously cold and draughty for a number of reasons:

- Gaps around the individual ‘quarries’ (the tiny panes of glass) reduce airtightness.
- Leaded panels are often set in metal frames, which are poorly fitted and draughty.
- The lead ‘cames’ holding the panel together act as thermal bridges, as does the metal frame.

Leaded lights in particularly poor condition may need to be repaired to address airtightness. Secondary glazing is usually a good solution to improve overall thermal performance, but it needs to be carried out in an aesthetically sensitive way.

It is worth overhauling leaded lights and considering secondary glazing.

Carefully installed, plastic panels with magnetic strip fixings can be discreet, and are an effective way of improving a window's thermal performance.

Secondary glazing – plastic

While it may sound like an unattractive option, and raises issues about using a petroleum-based product that is not always easy to recycle, plastic secondary glazing has advantages. It can be more discreet than glass and is particularly good for large windows where a non-opening, lift-out panel is required for the winter months only. Whereas glass is heavy and requires a subframe for support, the relative lightness of plastic panels means that they do not generally need a subframe – just a magnetic strip to hold the panel in position. This method of fixing is less visually obtrusive in the warmer months when the panel is being stored.

Specialist companies will carry out the installation of plastic secondary glazing, but it is also a DIY option and, if you measure the window and assemble the panel yourself, this type of glazing is much cheaper than glass. Plastic sheets – generally up to 4 mm thick – can be ordered cut to size, and are supplied with a self-adhesive magnetic strip to stick around the edge. A self-adhesive metal or magnetic strip is fitted to the window frame to hold the panel in place.

If your window is out of square or an unusual shape, you will probably require a bespoke solution manufactured from a template taken from the window. To check whether the window is square, measure the two diagonals; if they vary slightly it is not. Where plastic sheet needs to be cut on site, speak to your supplier about the best method.

Specialist installers are likely to be able to offer a greater range of solutions and will often overhaul the window at the same time as fitting the secondary glazing. One integrated system for sash windows involves adjusting the window so that the secondary glazing can be fixed directly to the face of the sashes, allowing them to slide normally. This approach necessitates fully draughtproofing the window, as the secondary glazing does not cover the surrounding frame.

Plastics for secondary glazing

Four principal plastics are used for secondary glazing. All are stronger than glass.

1. Acrylic, also known as perspex and plexiglass, has good optical qualities and does not suffer colour loss.

2. Clear polystyrene provides an economical form of secondary glazing, but is the least strong. It discolours and goes cloudy over time, particularly in direct sunlight.

3. PET (polyethylene terephthalate) offers clarity, good impact resistance and has an excellent fire rating.

4. Polycarbonate is highly impact resistant but is easier to scratch than acrylic. It is ideal for windows that require a security upgrade and has an excellent fire rating.

The frame to this leaded light window did not have a continuous flat plane around the edge, so it had to be adapted before secondary glazing could be fitted. In some cases it will be necessarily to build the frame out to accommodate protruding window catches and latches.

Wooden strips are fitted each side to pack out the frame to prepare for secondary glazing.

A steel strip with self-adhesive backing is stuck to the frame. Note: if a double magnetic strip is used, the strip cannot be fitted separately, but must be offered up with the panel.

The steel strip is painted in with the frame and becomes largely invisible during the summer when the panel is removed.

Advantages of plastic secondary glazing over glass:

- The better-quality plastics are completely clear and are indistinguishable from glass.
- It is much lighter in weight, so is easy to remove for cleaning or during warmer months.
- Unlike glass, the panels are lightweight so do not require a trim or frame.
- Its thermal and acoustic performance is better than that of glass.

- It is generally cheaper than glass secondary glazing and DIY options are available.
- Plastic is more flexible than glass, so can adapt to old window frames that are out of true, allowing a more efficient perimeter seal.

Considerations when using plastic secondary glazing:

- The plastic will pick up a static charge very easily and attract fluff, so avoid contact with carpets during assembly.
- Plastic sheets are vulnerable to scratching. Keep them covered with their protective film as long as possible during fitting and take great care not to scratch them while cleaning.
- Check the combustibility of the plastic and associated fire risks.
- Unlike glass, plastic panels are hard to break so should be avoided where the window is likely to be the principal means of escape in the event of fire.

A self-adhesive magnetic strip is fitted around the edge of the panel.

The plastic panel is offered up to the window.

Magnetic systems

Plastic secondary glazing systems generally rely on magnets to hold the panels in place and are not designed to be opened. The rubberised self-adhesive magnetic strips – typically 12 mm to 20 mm wide – provide an unobtrusive fixing method. A strong magnetic strip is generally fitted to the panel, but this can be attracted to the frame with either a steel strip or, for the strongest fixing, a second magnetic strip. With the latter method the polarities of both magnets must be correctly aligned, otherwise they will repel rather than attract. This applies not just to which way round the

magnets are in relation to each other, but also to their edges, which must be in exact alignment on top of one another.

When installing a double magnetic strip system for the first time, the need to align the magnets exactly necessitates first pairing them with their partner on the panel. The backing tape is then peeled off and the panel is carefully positioned before being pushed into place so that, when the magnets adhere to the window frame, they are perfectly aligned. Unfortunately, this can result in an untidy detail on the window when the panel is removed, as the magnets will not necessarily be parallel with the edge of the frame. Where this is likely to be a problem, it is generally better to use metal strips on the window (rather than a second magnet) so that they can be positioned and aligned parallel to the window frame.

Where it is possible to hide them behind a blind or curtain, cable clips can serve as simple ‘latches’ to secure plastic secondary glazing in windy locations. This is a particularly useful technique on tall, narrow windows where the plastic panel is prone to sagging in the middle under its own weight.

In very windy locations, or if extra security is required, additional fixings may be needed to secure the secondary glazing sufficiently.

Poor-quality magnets and adhesives can be a problem and may fail, especially on south-facing elevations that are subject to extreme temperatures. High-specification self-adhesive magnetic strips combine a foam backing tape with the adhesive, helping to create a good seal between the secondary glazing and the window frame. This accommodates any unevenness to the surface on which it is stuck and helps absorb vibration that may cause rattles. The foam also provides draughtproofing and cuts sound transmission at the edges of the panels, restricts moisture access and creates a thermal break between the buildings's fabric and the secondary glazing.

Where secondary glazing will be removed during warmer weather, the strip fixed to the window frame can be painted the same colour as the woodwork to disguise it when the panel is not in place. After painting, it is vital to allow sufficient drying time – otherwise the panel may stick to the strips and be difficult to remove.

Clear plastic hooks allow plastic panels to be lifted out easily.

Removal and storage of panels

Glass and plastic magnetic secondary glazing can be removed in the warmer months to allow the windows to be opened and cleaned. Before lifting a panel, have a soft sheet ready to lie or lean it on. If you are removing numerous panels, make sure they are numbered to correspond to each window.

The bigger the window, the heavier and more unwieldy the secondary glazing becomes, making lifting out more difficult; any glass panel over 1 metre square generally requires two people to lift it. One of the easiest and safest ways of lifting and moving glass panels is to use the large suction cups designed for glass handling. These work less well with plastic, because of the flexibility of the panels, so smaller cups should be used.

Where it is difficult to get to the edges of the panel, and suction cups are not being used, make sure there is a means of removing the secondary glazing. Small, clear plastic hooks fixed discreetly to the corners of the panel are one solution. Alternatively, glue short lengths of strong ribbon to the inside of the panel under the magnetic strip, so that they hang on the outside and can be pulled to free the panel.

Before storing panels, protect them from scratching by wrapping them in a sheet or duvet cover, so that they can be stowed safely under a bed or at the back of a wardrobe. If you have a lot of panels and sufficient space, consider building purpose-made racks.

Before reinstalling secondary glazing, vacuum around the frame, clean windows, and gently wipe the panels following the manufacturer’s care instructions. Anti-static plastic and glass cleaners used in conjunction with a microfibre cloth are often suggested.

Suction cups make removing and handling large panels of secondary glazing easier.

Transparent shrink film is a quick and cheap temporary way to improve the performance of a draughty window.

Secondary glazing film

For a cheap and effective temporary solution, transparent shrink film, similar to cling film but designed for secondary glazing, may be fitted over the window frame. Usually fixed with double-sided tape, it pulls taut when heated with a hairdryer. This creates an air cavity to reduce heat loss, but it prevents the window from being opened.

Films that bond directly to glass should be avoided if the glass is thin and valuable, as they may cause damage. They offer only limited thermal enhancement as no air gap is created, and are generally installed to filter UV rays that harm fabrics and artwork.

DOUBLE GLAZING

In simple terms, double glazing consists of two sheets of glass combined in a single unit that is hermetically sealed around the edge, with the space between filled with air, a vacuum or other gases. This reduces the transfer of both heat and noise through the unit. Units are typically between 24 mm

and 28 mm thick and the seals create a border around the edge of at least 10 mm. Modern windows are designed with these dimensions in mind, and have wide and deep rebates to accommodate the unit.

Most traditional windows have a glazing bar with a shallow rebate, designed to take a single sheet of handmade glass, typically 3 mm, and a thin fillet of linseed oil putty. This means that it is usually impractical to replace old glass with standard 24 mm thick double-glazed units, as there is insufficient width or depth. Where new windows are manufactured to take double-glazed units, the glazing bars are often oversized and out of proportion with the window.

Where old handmade glass is still present, it is just as important as the historic timber frame that surrounds it. Even if it were possible, replacement with double glazing would change the way light is reflected, altering the character and beauty of the facade, and is unlikely to gain consent if a building is listed. Also bear in mind that the extra weight of a double-glazed unit may strain the hinges of old casement windows and will almost certainly unbalance sashes.

If using linseed oil putty or paint products with double glazing, ensure there is separation between them and the edge seal of the glazing unit as the oil will react with the seal, causing it to break down. The glazing supplier should provide information on how to achieve this.

Warranties for double glazing of all types vary enormously, but careful fitting and good window maintenance can increase the life of a double-glazed unit. A key issue is the problem of the edge seals failing and condensation forming within the unit. If buying double glazing, look for the best-quality units with the longest possible guarantee and those that meet relevant technical standards for double glazing. Most guarantees from glazing companies offer replacements for failed units but do not cover the cost of fitting or redecorating, which can be time-consuming and expensive.

A typical double-glazed window with a white spacer.

A failed double-glazed unit where condensation has formed.

Slender traditional glazing bars in a single-glazed window.

Chunky modern glazing bars are necessary to accommodate double-glazed units in a multi-pane window.

Slim-profile double-glazed units

Designed specifically for use in slender, traditionally sized glazing bars, slim-profile double-glazed units allow new windows to be made to thermally efficient standards while retaining historic proportions.

Some are filled with low-conductivity gases such as krypton and xenon and, at just 12 mm thick, are able to meet current building regulations for U-values. They are also available as thin as 10 mm, and some are manufactured with a narrow border of 5 mm. Where glazing bars are

slender, a border wider than this may be visible. Some units can be ordered with an outer layer of handmade glass to suit a particular style and age of house.

Vacuum-filled units are another option, as these are available with a thickness of just over 6 mm. While these sound like a good solution, they are manufactured with tiny spacers between the panes that appear as black dots on the glass, which may be visually unacceptable.

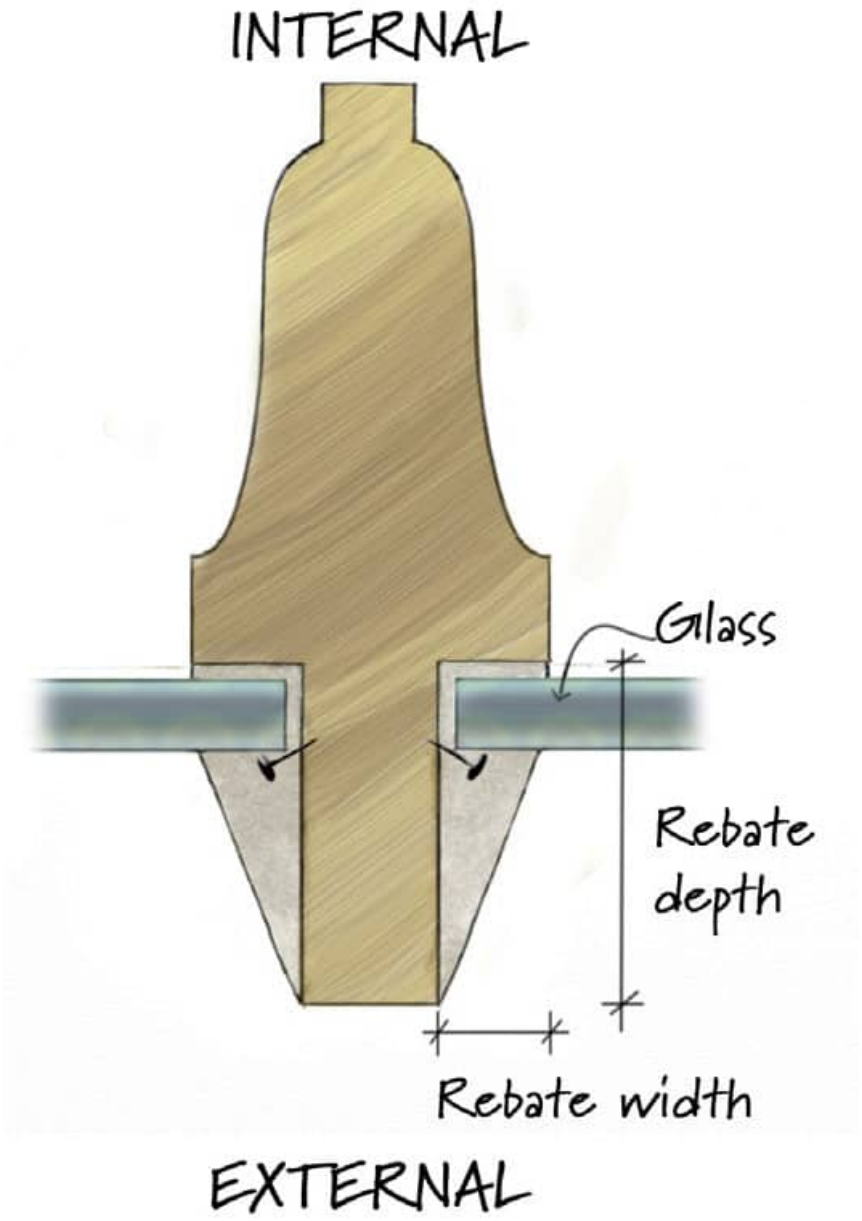
REPLACING MODERN WINDOWS

Unsurprisingly, where old windows have been replaced in the past with inappropriate PVCu or aluminium windows, many homeowners are keen to reinstate something more in keeping with the period of the house.

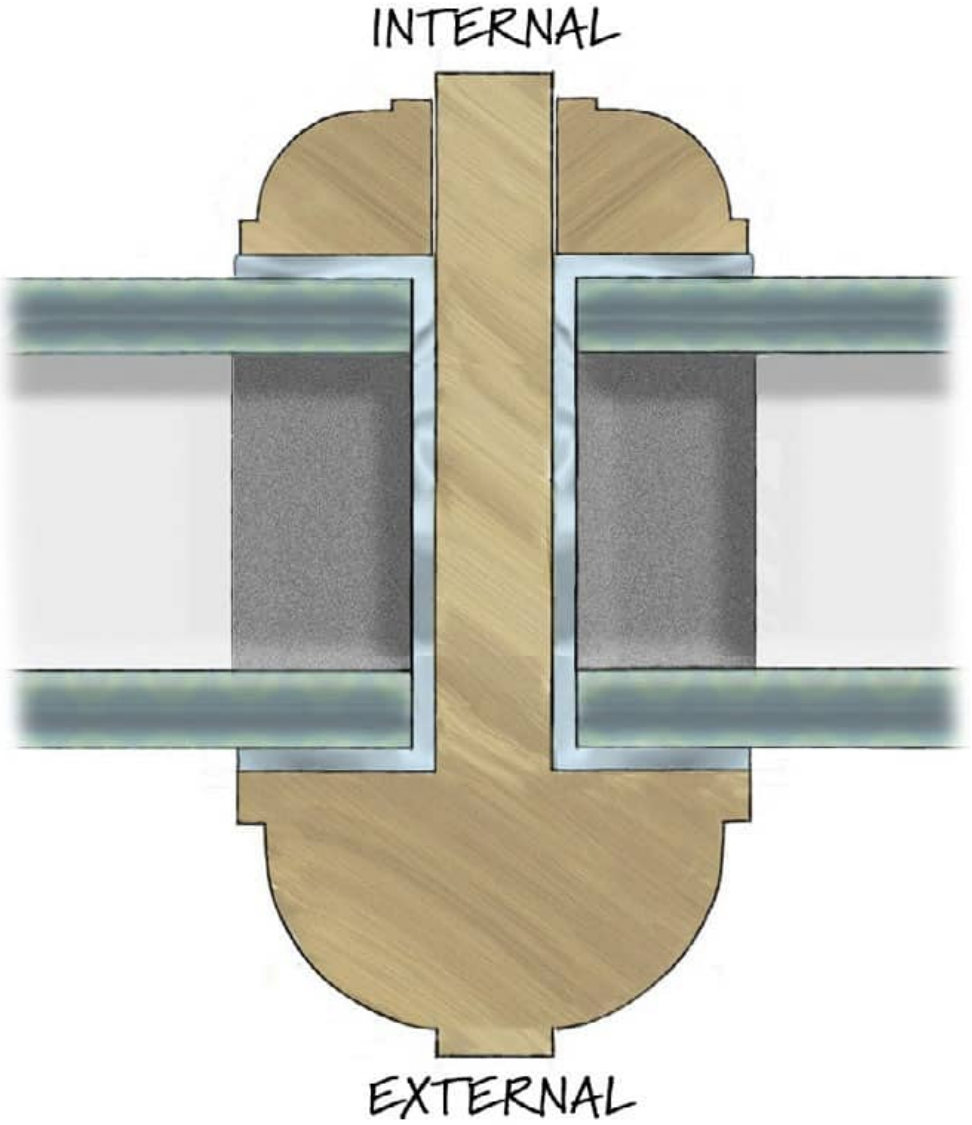
What are the options?

Generally when a window and frame are replaced, the new unit should meet current U-values, although these may be relaxed for certain period properties (See Building regulations, shown here). If your house is listed, you may find that your conservation officer insists on single glazing.

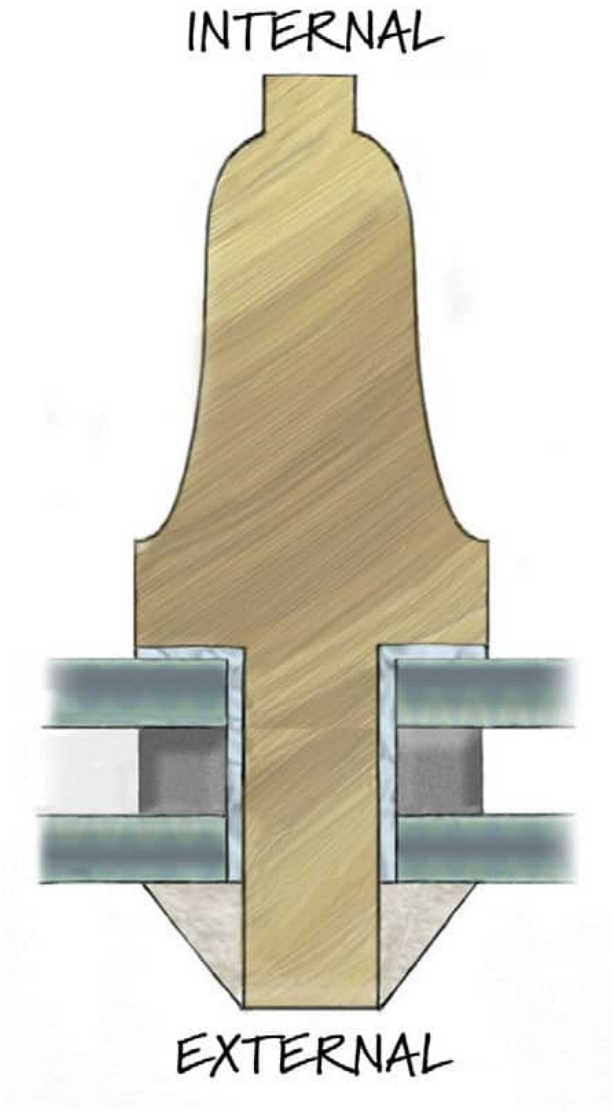
Ideally, new windows in period facades should combine the appearance and proportion of the old windows with a reasonable level of thermal performance. Regardless of whether the building is listed, it may be possible to fit a facsimile, traditional window with single-glazed, handmade glass. If you are commissioning a bespoke window, it can be designed to work in conjunction with a magnetic secondary glazed unit fitted within a purpose-made rebate. Such a solution should satisfy building control and, where appropriate, the conservation officer.



Traditional glazing bar with old glass The size and proportions of traditional glazing bars vary enormously. Here the rebate is 15 mm deep, allowing for a pane of 3 mm handmade glass, secured by sprigs (tiny nails) bedded in and weatherproofed with a fillet of linseed oil putty. Some rebate depths may be as little as 12 mm or less.



Modern glazing bar with standard unit. A modern double-glazed unit is typically 24 mm to 28 mm thick, with a wide visible border around the edge. Glazing bars to new windows are designed to fit the thicker units and to cover the border by having deeper and wider rebates. Most modern windows have internal wooden beads to secure the glazing units.



Traditional glazing bar with slim unit A 10 mm thick slim-profile unit will fit some existing glazing bars, but certainly not all. A rebate with a minimum depth of 18 mm is necessary. The new unit is held in place with high-modulus clear silicone, without the need for sprigs. If properly applied, this also makes the edge weathertight, prolonging the life of the window. A small fillet of linseed oil putty finishes the glazing bar in the traditional manner.

Low-E glass

Glass with a low-emissivity (Low-E) coating reflects radiant infrared energy rather than allowing it to pass through. Windows can be designed to reflect heat back into the room, making them more energy efficient during the winter, or to reflect solar gain, keeping the internal environment cool during the summer.

New windows fitted with slim-profile double glazing (see above) can achieve good U-values while allowing a traditional-section glazing bar to be incorporated in the design. For the best visual effect, the outer pane of glass can be specified as handmade but, with multi-pane windows consisting of many small panes, this comes at a price. If the seals to the slim-profile double-glazed units fail and the guarantee is no longer valid, it can become an expensive maintenance item.

It is now standard practice, even with high-quality wood window manufacturers, to simulate the appearance of a multi-pane window. Rather than the use of individual double-glazed units, a single, standard-thickness double-glazed unit is used with stuck-on or planted-on glazing bars. This must be done well and, to give a more convincing effect close up, the glazed unit should be fitted with spacers sandwiched between the two layers of glass to correspond with the line of the glazing bars. With superior-quality windows, the glazing bars are constructed as an independent, jointed framework to lay over the glass. Cheaper window producers will simply glue the glazing bars directly to the glass and these have a tendency to fall off, particularly during cleaning. If done well, this visual cheat will be almost indistinguishable from using individual double-glazed units and has a superior U-value to a multi-pane solution because a real glazing bar acts as a thermal bridge. Another advantage is that the glazing bar profile can be much thinner, as it does not need to conceal the edge of individual double-glazed units.

Slim-profile double glazing.

Spacers set within a double-glazed unit awaiting ‘planted-on’ glazing bars.

A window with stuck-on glazing bars but no spacer bars in between is unconvincing.

TOP TIP: DOUBLE-GLAZING SPACER BARS

Where double-glazed units are used, avoid aluminium or silver-coloured spacer bars which draw the eye. Instead, specify a spacer bar that is less visually obvious, such as black, white or cream.

DOORS

Doors have a variety of apertures that allow draughts to enter and addressing these will make a tremendous difference to energy efficiency. If

you put your finger over a traditional keyhole on a cold, windy day, you will notice a rush of cool air coming through. A simple, well-fitted keyhole cover – an escutcheon cover plate – fitted both inside and outside can significantly reduce the draught.

Letter plates are even worse when it comes to airtightness. There are various draught-reducing plastic flaps and plates that can be fitted over the slot on the inside of the door, but the simplest solution is a hinged wooden flap, or even a piece of heavy fabric that is insulated and weighted. Cat flaps should not be forgotten: look for versions with a rubber seal that close effectively.

‘Sausage’ draught excluders work well at the bottom of a draughty door. These are available to buy or can be made with fabric filled with fine gravel, bean bag balls, lentils or anything that gives a little weight and keeps it in place.

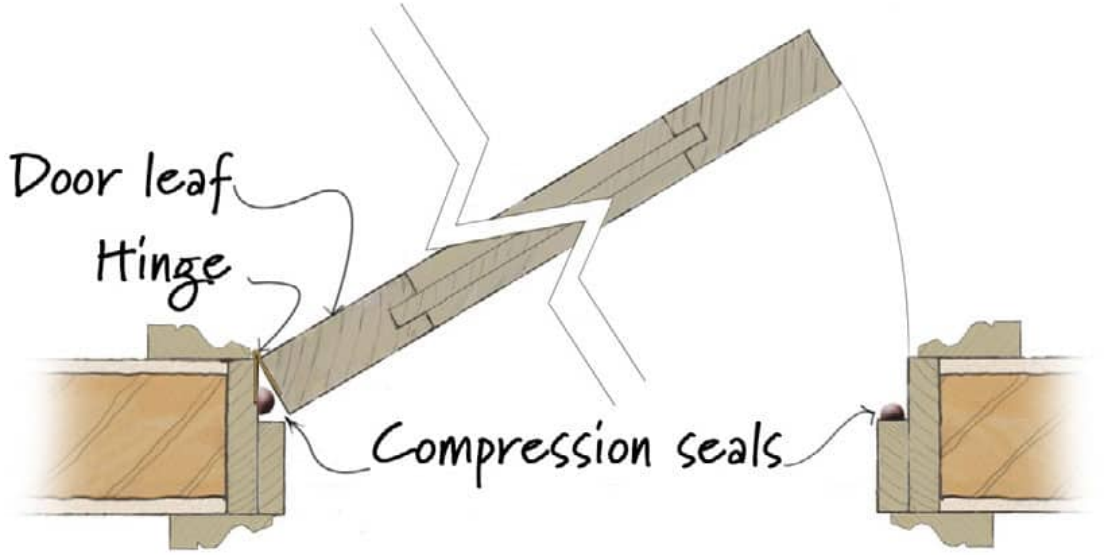
Old external doors rarely fit tightly in their frames. Over the decades they might have dropped slightly, their hinges may have loosened or the walls and floors around them settled. Often they swell and shrink in damp and warm weather, leading them to stick or rattle. Consequently, they will have been planed down to fit so, over time, the gaps around the edges become bigger. Shrinking and swelling problems are worst where the door’s edges have not been painted, so always ensure that all bare wood is properly finished, including the bottom and the slot behind the letter plate.

The simplest and most reversible draughtproofing solution is a rubber compression seal in a metal trim, which is pinned to the door lining. This is available from most DIY stores and usually comes in brass, copper or chrome finishes. It can be painted to match the frame, but it is visually rather intrusive and not particularly effective if the gaps are large. A brush seal can also be fitted to the base of the door on the internal face, where the draughts tend to be most noticeable. They allow the door to swing open and shut, but tend to be ugly.

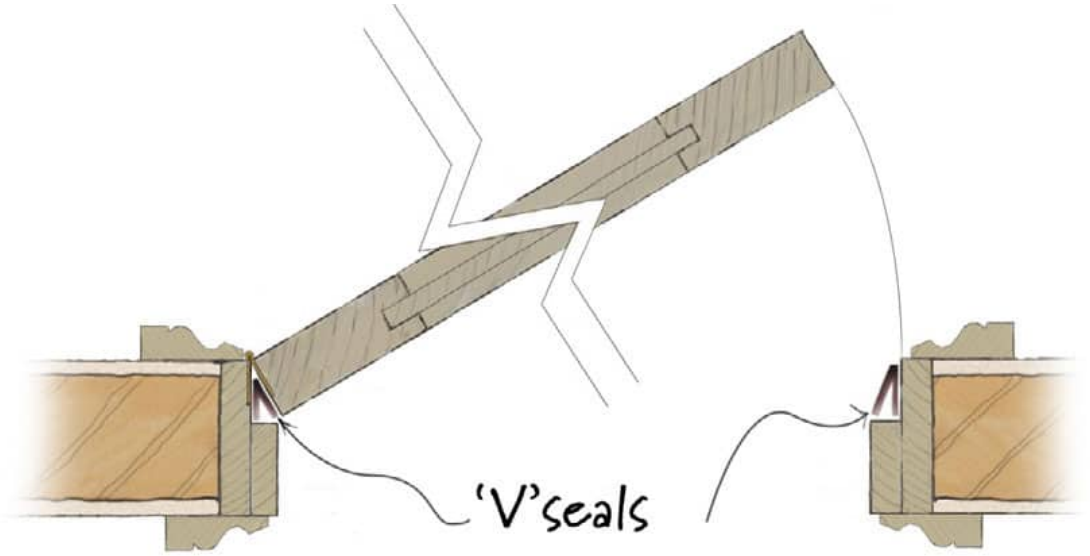
Professional draughtproofing is a much better solution and can be fitted to old doors in a similar way to windows, either to the edges of the door or, preferably, to the frame. The position of the seal depends on the type used,

so check with the manufacturer. Always employ an experienced joiner to carry out the work and opt for a good-quality seal.

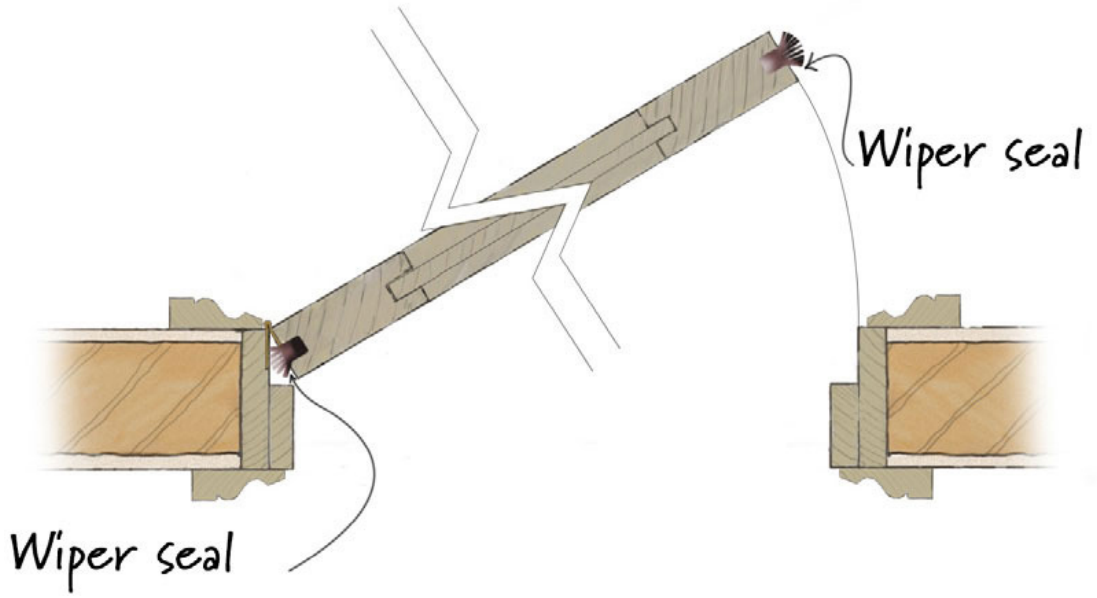
Old doors rarely fit tightly in their frames, so draughtproofing is a priority.



Compression seals are typically fitted to the stop on the meeting side of the door frame, and the lining on the hinge side. This way, both will be compressed when the door is closed, minimising air leakage.



V' seals are fitted to the door lining on all three sides.



Wiper seals can be fitted to the frame, but are more usually rebated into the edge of the door leaf.

A brass escutcheon plate and cover.

A porch adds character to a Victorian house, while also helping to keep out the cold.

Fanlights, like this simple example in a Georgian terraced house, were first introduced in the 1720s to bring natural light into hallways. Secondary glazing helps to upgrade their performance.

Depending on the design, it may be possible to insulate an old door. Aerogel insulation covered with plywood is a good option where it can be fitted within the sunken panels on the door's inner face. These may then be trimmed with wooden beading to cover the junction and maintain the appearance of the door.

Fanlights above doors are particularly suited to secondary glazing which, in addition, can provide valuable extra security.

Door curtains

Portière rods are a traditional method of hanging a curtain against a door to provide insulation, so that it opens and closes with it. A prop is fixed to the door leaf, which supports the end of a curtain pole while allowing it to slide along when the door is in motion. Door curtains should be heavily lined but should not touch the floor, as they will become snarled in the gap under the door.

PORCHES AND VESTIBULES

Every time an external door is opened and closed, a large volume of warm air is lost and replaced with cold air from the outside. One way of resolving this problem is to create an ‘airlock’ by adding a second door, so that only one door need be open at any time.

Where there is space internally, this can be achieved by creating a vestibule; alternatively, a porch might be utilised externally. Whichever solution is chosen, it should be large enough so the inner and outer doors do not have to be opened simultaneously, otherwise the benefits of the airlock will be lost. By creating a porch or vestibule, the old front door can be left in its original condition and the main insulation and draughtproofing introduced to the new, second door. This solution has the added benefit of cutting down traffic noise on busy roads.

Ideally, where there is room, it is useful to provide hanging space so that wet clothes can be removed and hung within the porch or vestibule, minimising the moisture that is brought into the body of the house. A small radiator to provide a background heat source, perhaps below a porch seat, will help prevent mould or mildew on clothes hanging above.

The creation of a vestibule through the addition of a door and partition is particularly suited to Victorian layouts, where the front door leads to a long corridor. A glazed inner door will allow borrowed light into the interior. Ideally the door should be designed to open flat against the wall, so that it can be hooked back in the warmer months when an airlock is not required.

07 | WALLS

Traditional solid walls pose huge questions when it comes to deciding on insulation; in some situations, wall insulation may be best avoided altogether. Inappropriate solutions risk considerable damage to the building's structure, character and the wellbeing of its occupants.

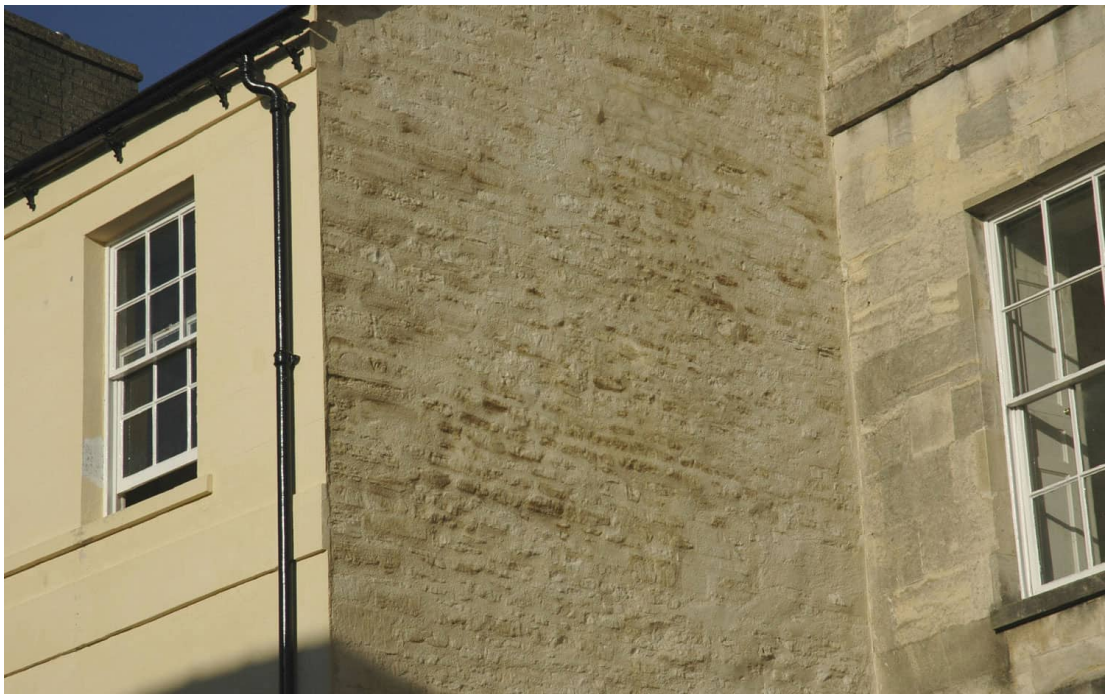
Not only do old walls vary enormously in their thickness and construction, but their performance also differs according to their orientation and location. What they have in common is that, until about a hundred years ago, they were constructed using permeable materials including lime and earth mortars, renders and plasters, and are able to breathe. Breathability allows water, in the form of vapour or liquid, to pass readily through the body of the wall and either escape or be redistributed within it.

With thermal insulation often high on the retrofit agenda, many firms offer quick and easy solutions for insulating old walls without understanding the long-term consequences. It is crucial to find a solution that is compatible with their breathable characteristics, rather than imposing a system that is designed for modern cavity construction.

Although adding insulation can improve the thermal efficiency of walls in the short term, it can potentially act as a barrier to the natural breathing process, trapping moisture and causing interstitial condensation within the thickness, or 'interstices', of the wall. Wind-driven rain poses a particular risk with certain systems in exposed locations, as solid walls are less able to dry out once insulation has been installed. Damp walls are less thermally efficient than dry walls and problems may be hidden and remain undetected once an internal insulation board has been fixed. Decay and mould growth can result, which is damaging both to the building fabric and human health.

Regional variations in construction and exposure to sun and wind-driven rain are important factors when deciding how best to insulate walls.

Every house is unique and wall insulation will not be appropriate for all. A good understanding of the building's construction and situation will dictate the options available.



Breathing walls are given special consideration under the Building Regulations, and should not be insulated if there is a potential risk of deterioration.

Leaking rainwater goods cause water to run down walls, resulting in damage and decay to the building's structure; wet walls are also thermally inefficient.

BUILDING REGULATIONS

In 1965, when U-values were first introduced, new walls had to meet a target of 1.7 W/m²K. This is achieved with a standard, unfilled cavity wall. Since then, the target U-value has been dramatically tightened for 'retained thermal elements'. Existing walls must be upgraded to comply with current U-values under the circumstances listed shown here, although the regulations accept that internal insulation is not appropriate if it reduces the floor area by more than 5 per cent.

The Building Regulations recognise that ‘buildings of traditional construction with permeable fabric’ need to be treated in a way that allows them to breathe, and that any alterations should ‘improve energy efficiency as far as is reasonably practicable’. The regulations therefore should not require the use of a non-breathable type of insulation with a traditional, solid-walled structure. They go on to say, ‘The work should not prejudice the character of the host building or increase the risk of long-term deterioration…’. This is particularly helpful for anyone who does not want to be forced to install inappropriate insulation. The wording of the section makes it possible to negotiate a compatible solution with the building control officer.

WET WALLS ARE COLD

A damp wall will be considerably less thermally efficient than a dry wall, as water is a better thermal conductor than the air it is replacing. The latent heat of evaporation also has an effect, cooling the wall as it evaporates moisture. SPAB research suggests that up to 40 per cent more heat is lost through a damp wall than through a dry wall. Before even considering any type of wall insulation, it is essential to ensure your existing walls are dry by checking their condition, addressing any maintenance issues and allowing them to breathe through the use of lime or earth mortars, renders and plasters.

If the house has exposed masonry with pointing:

- Check the pointing is in good order.
- Where the pointing has been replaced with cement and is trapping damp, consider replacing it with lime so that the wall can breathe.

If the house is rendered:

- Check whether the surface of the render is cracked; even small cracks will draw in rain via capillary action.
- If the render is cement, investigate whether it is trapping moisture and, if so, consider replacing it with a lime render.

- If it is lime render, check whether it is finished with a breathable paint such as limewash. Modern masonry paints can stop a lime render from breathing.

It is worth monitoring the performance of gutters, downpipes and gullies during heavy rain to ensure that they are channelling water away rather than allowing it to run down the wall. Consider whether leaking drains or pipes, raised external ground levels or other factors are contributing to dampness in the wall.

Cement pointing is carefully removed from this early nineteenth-century wall to allow it to breathe and dry out. Once repaired, it will be repointed with traditional lime mortar.

If you are in any doubt whether walls are damp, get them checked by a competent surveyor specialising in solid-wall construction. Do not rely on a twin probe or non-invasive electrical moisture meter on the inside face of the wall: either could be picking up surface condensation, salts or even foil-backed plasterboard.

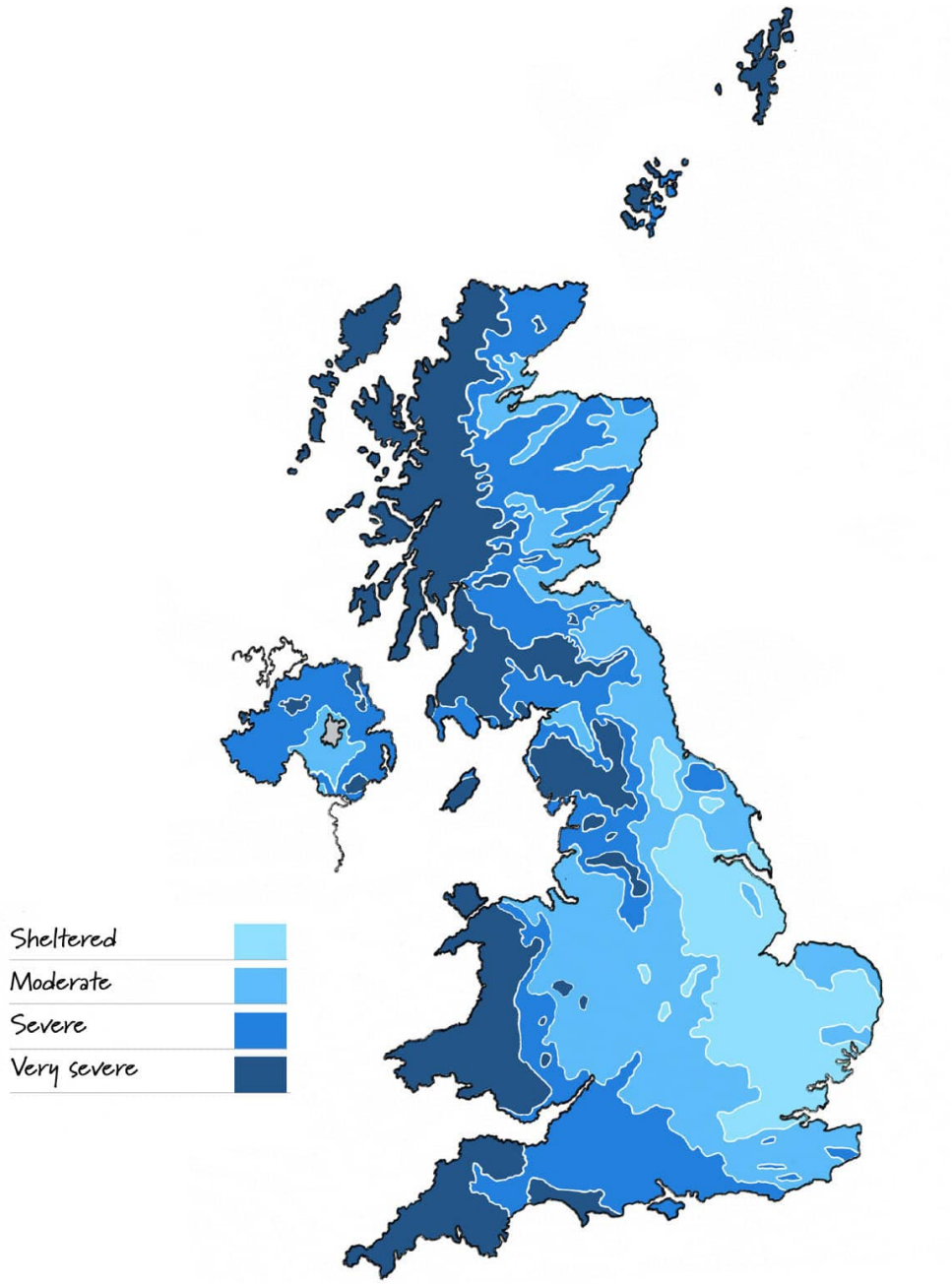
Once the causes of damp problems have been resolved, the thermal performance of the wall may be strikingly improved without the need to add insulation.

Location, location, location

A building's exposure to wind-driven rain varies enormously according to its location. The west coast of Scotland, for instance, will be subjected to over three times the amount of rain as London.

In severely exposed locations, it may be more effective to focus on simply weatherproofing the outside to keep the wall dry, rather than trying to insulate the inside. In order to keep water out, various traditions have evolved along the west coast of the UK, such as slate-hanging and roughcasting or harling. The use of a lime roughcast finished with limewash covers any cracks in the wall and blocks the majority of wind-driven rain. The knobbly texture vastly increases the surface area, and any water that is absorbed is rapidly evaporated through its vapour-permeable structure after a downpour of rain. Over the last hundred years, the fashion for removing these 'rainscreens' and protective coatings, often to expose the rubble stone, has completely ignored their value in terms of keeping the wall dry. More recently, rubble walls have been repointed or rendered with hard, cement-based materials, which tend to trap moisture behind them. By removing external cementitious finishes and replacing with lime-based, vapour-permeable alternatives or traditional cladding, the thermal efficiency of a wall in an exposed location may be dramatically improved (See Which houses are at risk?, shown here).

A lime roughcast or harling is a good way of minimising the effects of wind-driven rain and maximising evaporation to a damp wall.



Map showing the categories of exposure to wind-driven rain in the UK. The location and orientation of a building need to be taken into account when considering any retrofit solution.

The lime test

To check whether mortar or render is composed of lime (as opposed to cement), place the pointed tip of a sharp knife against the wall and lean on it. If the tip sinks in, it is most likely lime; if it does not, it is almost certainly cement. Cement mortars and renders may contribute to dampness within a wall, particularly if they are in poor condition. In such cases, replacing them with a lime-based mortar or render will allow the wall to dry out over time, improving the thermal efficiency of the structure.

The tip of a blade sinks into lime mortar (above), but cannot penetrate cement (below). Take care that the blade does not suddenly snap shut.

How does a wet wall dry out?

Assuming all defects such as leaking rainwater goods or defective pointing have been resolved, walls generally dry out through the following mechanisms:

- External evaporation: the most effective drying mechanism is through evaporation from the external surface, aided by the action of wind and sun.
- Vapour diffusion: this is driven by a vapour pressure differential that pushes moisture vapour from within the wall towards the internal or external surface.
- Heat flow: heat loss from the internal environment converts liquid water in the core into water vapour, which can then be diffused to the outside surface.
- Internal evaporation: severely damp walls may also evaporate moisture through the internal surface, provided it is plastered and decorated with breathable materials.

All of these mechanisms rely on the wall being able to breathe, so permeable finishes play an important role in keeping the wall dry (See Understanding breathability, shown here).

Slate-hanging in a Cornish coastal town.

This exposed building in Orkney absorbs and evaporates moisture through the wall's breathable lime finish.

HOW DO WALLS COMPARE?

It has long been assumed that old walls are cold walls, when compared to modern construction with insulated cavities. But how much do we really know? A wide range of walling materials, new and old, have been laboratory tested and assigned a value for thermal conductivity. These values have been accepted and used in computer modelling when calculating U-values for different buildings. For instance, thick cob walls (made of earth and straw) have a theoretical U-value that does not meet current building regulations for thermal performance yet, anecdotally, cob buildings perform extremely well, keeping occupants warm in winter and cool in summer.

The SPAB, along with other heritage bodies, has measured the U-values of traditional in-situ walls over several years to try to understand this discrepancy between theoretical and anecdotal thermal performance. Results from the SPAB's research have been compared with existing

thermal modelling data, and revealed that in over three-quarters of cases, traditional walls performed much better than predicted.

How wet does your wall get?

It is estimated that 30 per cent of driving rain splashes off vertical wall surfaces. The remaining 70 per cent could potentially be absorbed into the wall. Just how wet your wall gets largely depends on:

- Location: buildings on the UK's west coast receive much higher levels of rainfall.
- Orientation: south-westerly elevations are generally exposed to greater levels of driving rain, due to wind direction.
- Wall surface: the liquid water diffusion and wicking characteristics of a particular wall surface dictate how much moisture is absorbed (See Understanding breathability, shown here). Granite has a very low rate of absorption, compared to a soft stone or brick.
- Condition: the condition of mortar joints and the presence of cracks.

The U-value of rubble walls, in particular, was found to be far better than previously accepted. This is because they contain air voids, lumps of earth and lime-based mortars that improve the thermal performance of the wall. Calculated U-values do not necessarily take account of this. Wattle-and-daub is also a better insulator than is theoretically assumed.

With results gained from around the country, the SPAB has built a database of U-values for a wide variety of traditional materials and construction types. This will help to improve the accuracy of thermal modelling data in the future and inform decisions made when retrofitting for insulation (See SPAB U-value research, Report 1 on the SPAB website). So what type of construction performs best?

- Thicker walls perform better than thin walls. For instance, rubble-stone and cob walls, built to thicknesses typically of 600 mm upwards, perform better than 9 inch (225 mm) brickwork. They do, however, take longer to warm up due to their higher thermal mass, and work best when low-level constant heating regimes are employed.
- Walls with sound external lime renders, or traditional rainscreens such as tile-hanging or weatherboarding. These help to keep the core of the wall dry, particularly in exposed situations.
- Walls containing a large proportion of lime or earth mortar. Mortar is less thermally conductive than stone, so rubble-stone walls with a larger

proportion of mortar, especially at their core, are likely to out perform ashlar or brick walls, which have narrow mortar joints.

- Walls made of less conductive material. Daub and cob, both mixed with straw, are better insulators than brick and stone.
- Walls with minimal gaps and a reasonable degree of airtightness. Traditional timber-framed houses often have gaps around the edges of the infill panels and in the joints of the frame, making them less airtight and more draughty. Heat is transferred many times faster by convection through a crack than by conduction through solid materials.
- Walls with smaller windows and fewer openings.
- Dry walls always perform better than damp walls: regular maintenance is crucial.

Defective and poorly maintained rainwater goods are a primary cause of penetrating damp.

This house in Lancashire has thick, rubble-stone walls containing a large volume of mortar and air voids: it performs better in reality than in theory.

Heat flux monitors and temperature sensors were fixed to a variety of wall types to measure U-values as part of the SPAB's research.

AIRTIGHTNESS OF SOLID WALLS

The role of plaster and render in thermal performance is often overlooked. A BRE study discovered that 9 inch (225 mm) solid brick walls had, on average, only 67 per cent of joints and cavities filled with mortar. The missing mortar to the remaining 33 per cent could potentially provide paths for draughts and air movement within and through the wall. A good level of airtightness can be achieved by a continuous coat of internal plaster. As part of the airtightness strategy, old lime plaster should be retained wherever possible and cracks filled, particularly those between the wall and ceiling junction. Retaining original plaster has the added benefit of preserving historic finishes; the cost of removal and disposal will also be saved.

Lime plaster contributes to airtightness but, to ensure breathability, it must be stripped of impermeable paints and other finishes before insulation is applied.

INSULATING SOLID WALLS

Insulating the walls of solid-walled structures is highly controversial and technically difficult. In terms of authenticity, much of the beauty of an old

room comes from the imperfections of undulating old lime plaster. Replacing it or covering it with a flat and lifeless modern insulation material can destroy character that may have taken hundreds of years to develop and, very often, internal insulation is simply not an option. Equally, most old buildings have external details, finishes and historic patina that would be lost if insulation was fitted to the outside of the wall.

Even on walls where it is acceptable to cover the internal or external surface with insulation, there is much disagreement about how it should be done. Some experts suggest that many of the products on the market will create problems associated with mould growth, trapped moisture and decay in the future. It is very difficult to accurately forecast the effect of insulation on a solid wall over a long period of time. The factors that determine the outcome are so numerous and unique to each building that they are difficult to predict.

Large gable ends with few window or door openings may be worth insulating, particularly if they are north-facing. In this case, a number of issues would need to be resolved before an external system could be fitted.

If in doubt, leave it out

An old house may have been around for centuries and, with careful maintenance and informed choices, could last for many more. Never take a gamble on so-called ‘improvements’ that may compromise its longevity, particularly with regard to insulation. If in any doubt, defer the decision until products and systems have been tried and tested and there is a better general understanding of the potential problems.

Every old house has a unique set of challenges. This mid-terrace stone building in Dorset has a large proportion of glazing to the front elevation, and the technical challenges of wall insulation are unlikely to be worth the risk.

Where the window area forms a large proportion of the elevation, wall insulation is of little benefit.

The first question to consider is whether wall insulation is appropriate or practical. Analyse the benefits and ask: ‘What difference will wall insulation really make?’ If the wall area is relatively small compared to the glazed areas and doorways, and insulation is technically difficult to achieve, it may be best to leave the wall well alone; for example, in a mid-terrace

house with large sash windows. Conversely, an end of terrace will usually have a large external gable wall that may be losing an unacceptable amount of heat, so insulation is worth exploring.

Where wall insulation is considered necessary, a huge number of products and systems are available. While these can perform exceptionally well when used in conjunction with modern walls, many are inappropriate for older buildings. Genuinely breathable products are far more compatible with solid walls, as they do not trap damp, although they do rely on good detailing and are not appropriate for all situations. Do not opt for the cheapest ‘quick fix’ solution; it may be a false economy in the longer term if it causes damage to the structure or devalues the house due to the loss of historic features. If you are planning to insulate your walls, take impartial advice from a qualified person specialising in traditional construction.

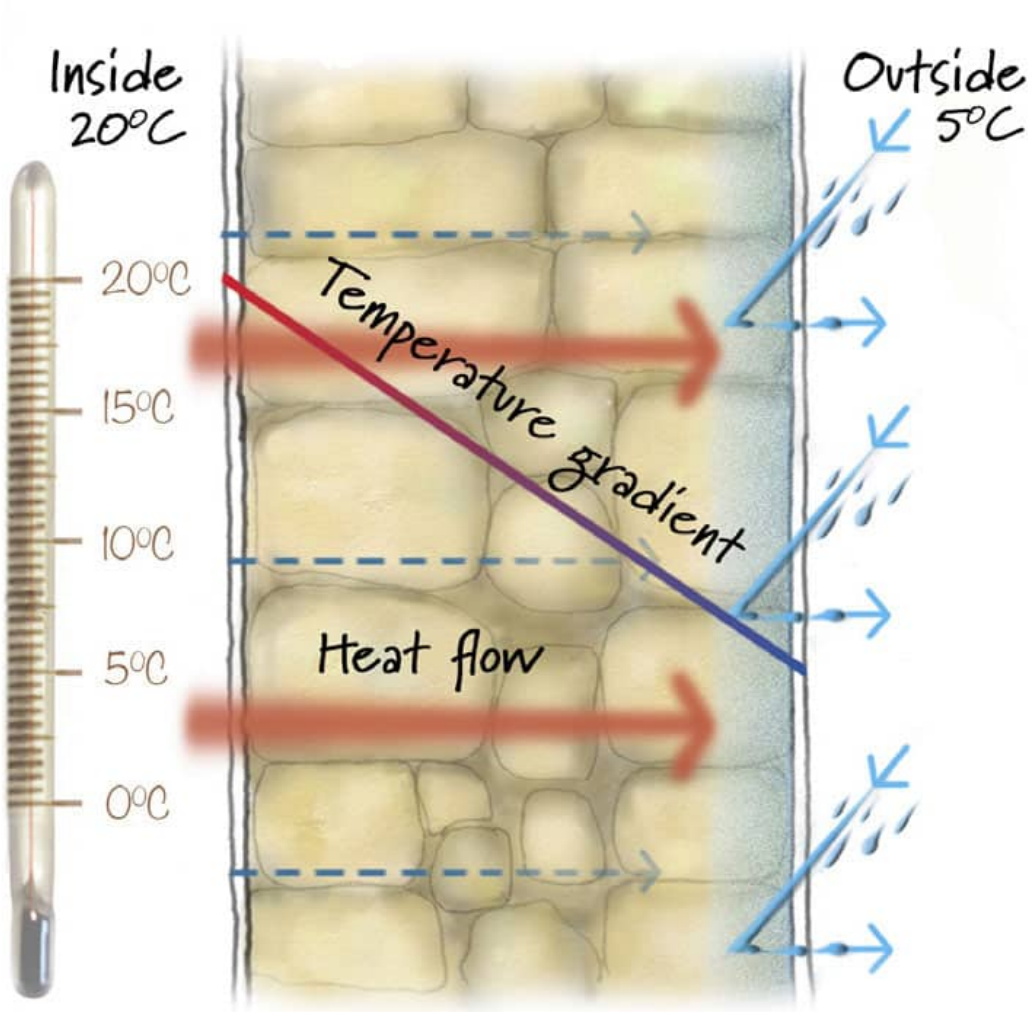
Inside or out?

There are generally just two options for improving the thermal performance of solid walls in old houses: insulating externally or internally. Both usually result in the loss of period features. The decision about where to insulate must take into account a variety of factors, including the wall’s construction, thickness, orientation, location and exposure, while each building type needs to be considered separately. In some cases a combination of external and internal insulation, used on different elevations, may be an option.

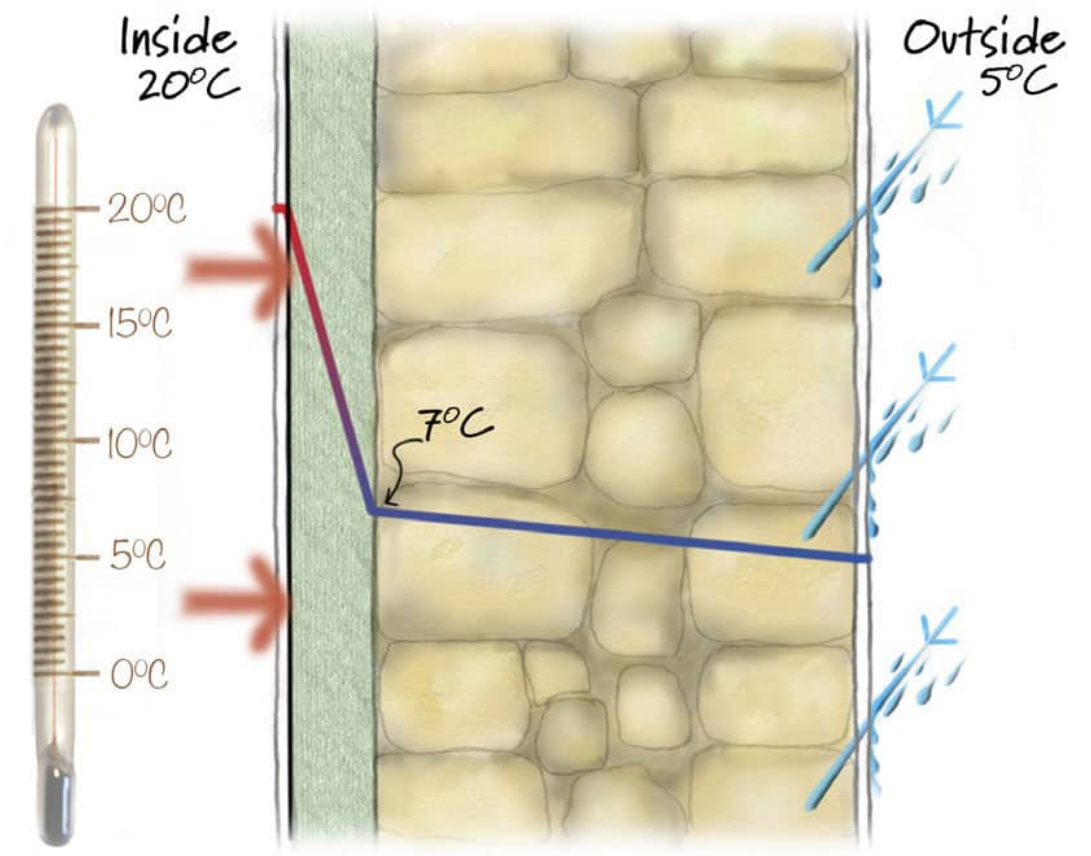
The way a house is used is also relevant. If it is occupied throughout the day and is heated with constant, low-level underfloor heating, for instance, an external insulation system will exploit the thermal mass of the masonry walls and help to level out internal temperature fluctuations. If the building is largely empty during the day, and intermittent heating comes on just morning and evening, internal insulation will be more thermally responsive. Whichever solution is finally agreed, it is crucial that it is well detailed and supervised by professionals with expertise in the type of building involved. The more complex the solution, the more care needs to be taken when installing or fitting, so the choice of contractor, coupled with on-site supervision, becomes critical. Above all, always check that the solution

proposed is ultimately compatible with the building’s fabric over the longer term.

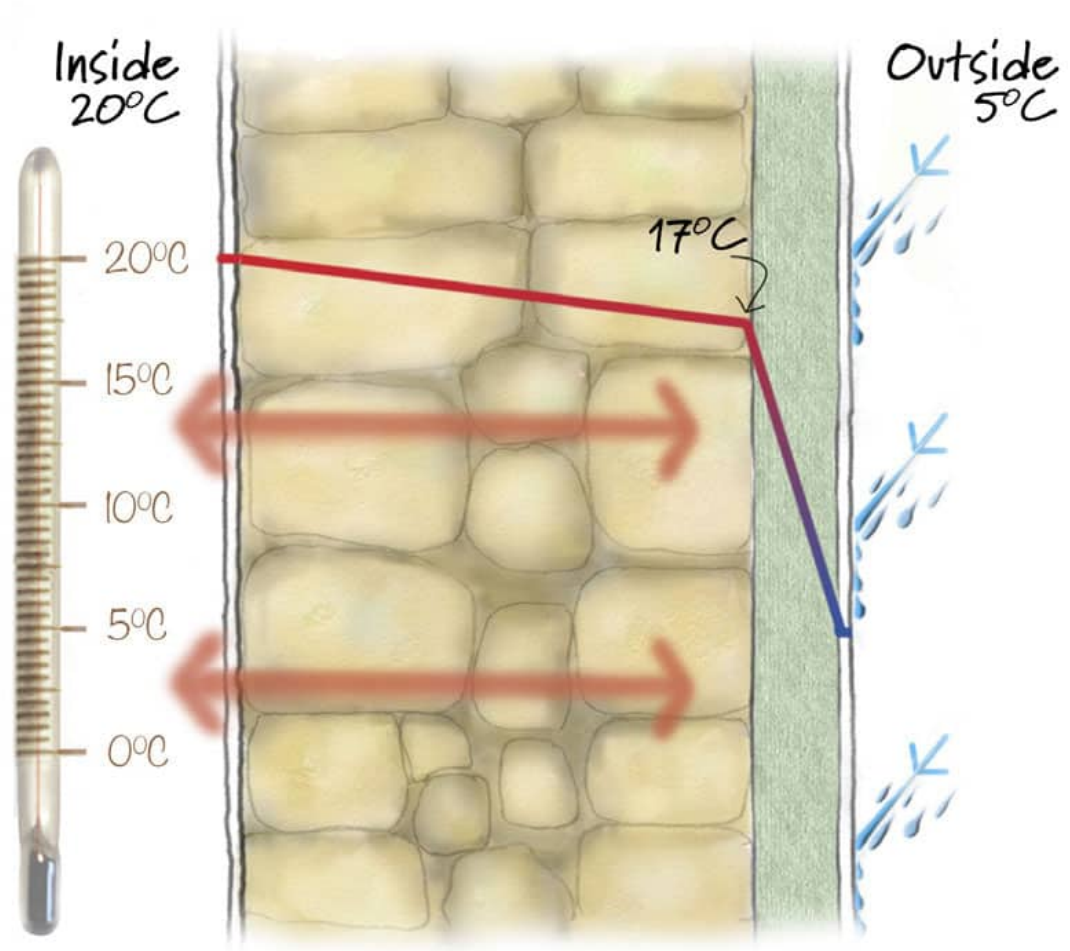
External wall insulation can sometimes be difficult with complex features such as bay windows, stone cills or narrow window frames. The risk of incomplete insulation coverage can lead to thermal bridging, resulting in internal condensation and mould.



This section through an uninsulated rubble stone wall shows heat being lost via conduction, or 'heat flow', indicated by the red arrows. The temperature gradient (the sloping line) can be read off against the thermometer to indicate the temperature across the wall. Internally, this is 20°C and externally, 5°C – a typical winter scenario. As the wall construction is the same all the way through, the temperature drops uniformly across its width. The breathable construction allows internal water vapour to pass through the wall and driving rain may penetrate the outside surface and be drawn in via capillary action (see the blue dotted lines). Over time this moisture evaporates to the outside, assisted by heat flow through the wall.



When internal wall insulation is added, heat flow is blocked at the inside face and prevented from passing through to the body of the wall. The temperature gradient, in this instance for a cold winter's day, shows a drop across the thickness of the insulation from 20°C on the inside to just 7°C at the point where it meets the masonry. As a result, the wall is now cold. This is a very different situation to the uninsulated wall shown in the previous diagram, where the centre of the masonry is still relatively warm. The cold masonry has implications for any water vapour in the body of the wall, as it is at risk of condensing if it reaches 'dewpoint temperature' (See Condensation and dewpoint, shown here).



When external insulation is added, the temperature gradient is dramatically altered once again, showing just a few degrees' change across the thickness of the masonry. This time, heat flow is largely blocked by the layer of insulation on the outside and the wall remains warm, re-releasing heat back into the room under certain conditions. With the outside temperature still at 5°C, the majority of the temperature drop now occurs across the insulation layer, shown by the steeper gradient.

INTERNAL INSULATION

Adding insulation to internal wall surfaces may involve the loss of original period features such as cornicing, skirtings and architraves. For a house with uneven walls and soft undulating lime plaster, many insulation systems will further destroy the character of the interior by leaving it with flat and lifeless finishes. From a practical perspective, the thickness of insulation will make rooms smaller and may make areas such as stairwells too narrow. Besides these issues, the technical ramifications of an inappropriate system may be far more damaging due to increased damp levels within the wall.

Insulation is fitted between studwork, but not all products have moisture-buffering properties.

With an ill-conceived or poorly installed system, there are two major risks: interstitial condensation caused by water vapour from within the room, and increased dampness due to driving rain. Both can result in serious structural issues as there is a very real possibility that any timber elements within the wall, such as embedded joist ends, bonding timbers and lintels, will rot due to the increased moisture content (See Embedded joist ends, shown here).

Insulated studwork and VCLs

Insulated studwork systems, creating a dry lining, have been the standard solution for internal retrofits for several decades. While systems vary, they generally consist of timber or lightweight metal studs fixed to the internal wall with mineral wool batts or foil-faced foam boards between. Insulated plasterboard is usually fitted over the top with a gypsum plaster skim.

A vapour control layer (VCL) is a crucial part of this system and should be on the warm side of the insulation. VCLs are designed to minimise moisture

vapour passing through from the room to the wall and condensing on the cold surface of the masonry. Where foam board is used, the foil face of the board can act as a VCL provided it is properly taped at all junctions and not punctured. Foil-backed plasterboard functions in a similar way. In theory VCLs should work but, in reality, it's very difficult to ensure a comprehensive vapour-tight layer.

VCLs are often poorly installed and not properly sealed at the junctions and edges. They are extremely vulnerable to damage and often punctured when electrical and other services are installed or pictures are hung. Any breach of the VCL could result in interstitial condensation that becomes trapped and unable to dry out (See Condensation and dewpoint, shown here). Where VCLs are necessary, consider using an intelligent membrane (See Intelligent membranes, shown here).

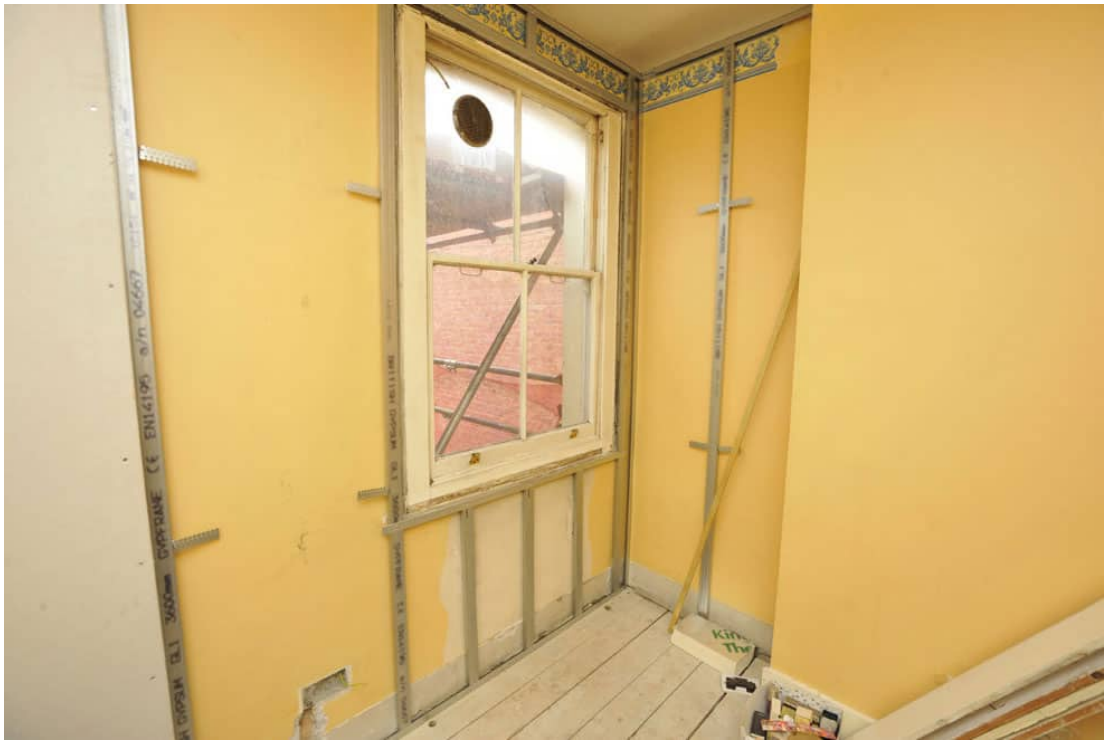
As well as condensation risk, other issues associated with this type of internal insulation include:

- Risk of decay to timber studwork.
- Use of non-moisture-buffering materials that cannot cope with moisture movement.
- Flat, modern finishes that are visually at odds with historic interiors.
- Risk of forming unventilated voids on the cold side of the insulation that are vulnerable to mould.
- Lack of breathability and risk of trapping driving rain in exposed situations.

Vapour control without membranes

Concern regarding trapped moisture, and the over-reliance on membranes for vapour control, has led to the design of a new generation of breathable internal insulation systems without membranes. Many leading retrofit designers now actively avoid the use of membranes as VCLs. Instead, specifically formulated breathable finishing plasters reduce the amount of vapour passing through to acceptable levels, taking the place of a membrane and acting as an airtightness layer. The moisture-buffering

insulation boards behind are able to manage normal levels of dampness within the wall.



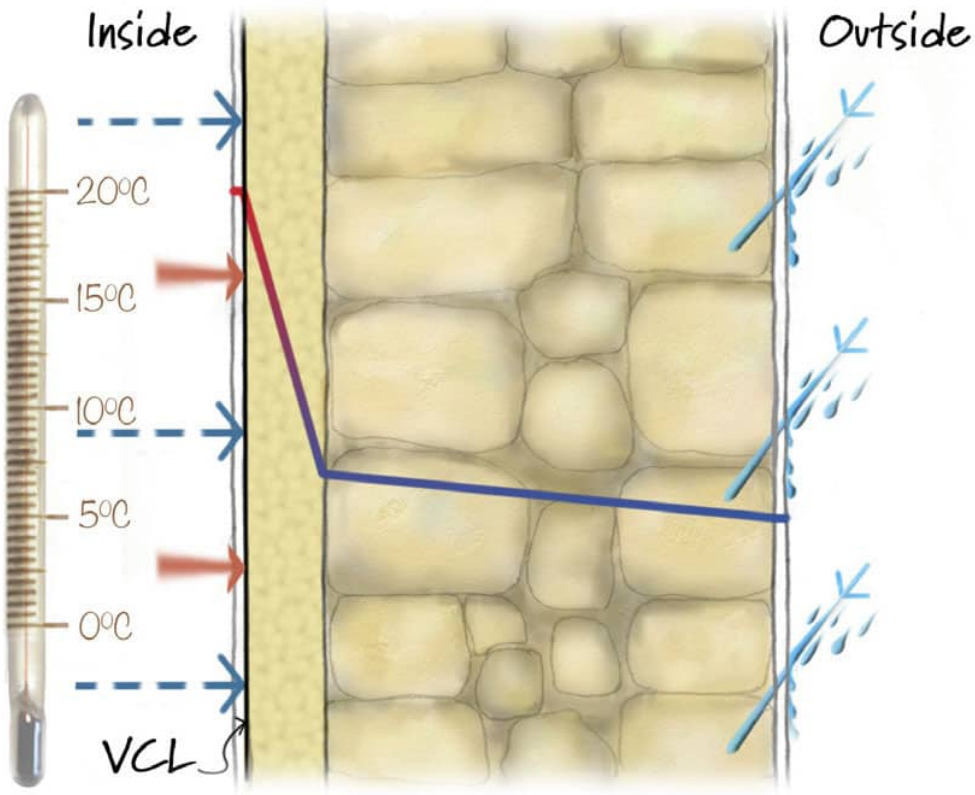
Proprietary dry-lining system using metal studwork.

Driving rain

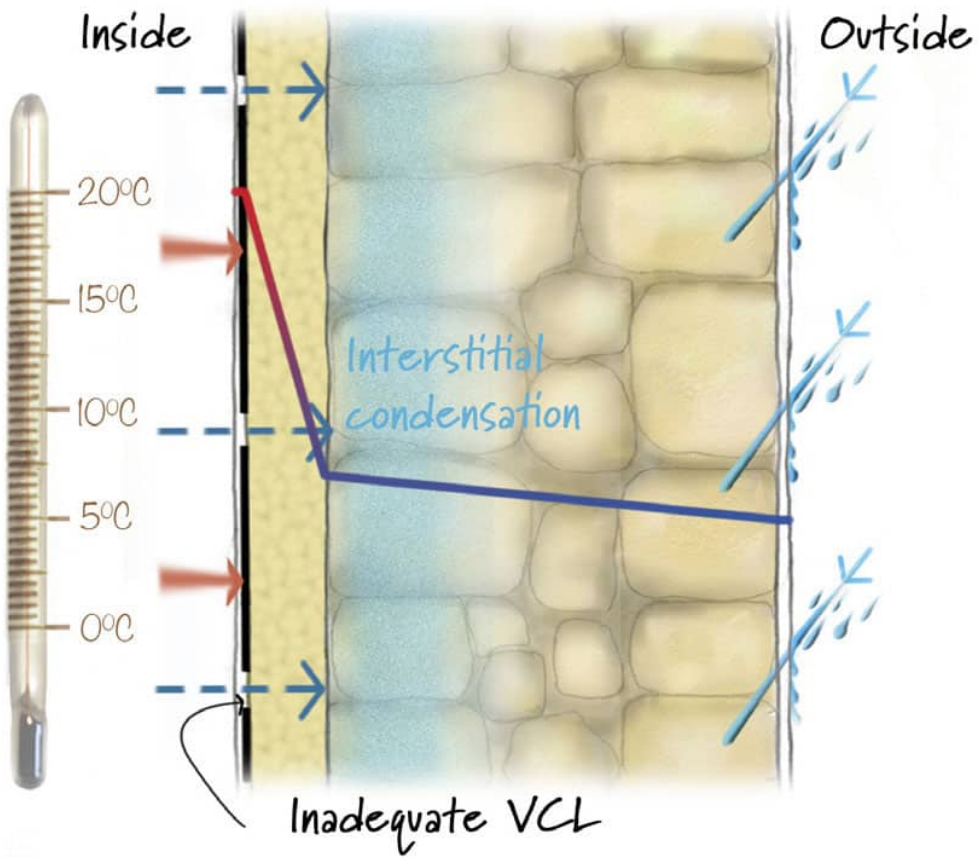
As well as interstitial condensation, there is an even more complex problem with VCLs and non-breathable internal insulation systems that is often overlooked. When wind-driven rain hits the external face of a wall, it may be drawn in via capillary action, depending on the wicking characteristics of the brick or stone. In extreme circumstances, rain may track across a solid wall, and a breathable inner face becomes crucial to allow moisture to evaporate into the room (See Location, location, location, shown here). If a VCL or impermeable system has been inserted, moisture in the core might become trapped behind it and be unable to escape.

Manufacturers of internal insulation systems may recommend treating the outside face of the wall with a breathable hydrophobic primer or hydrophobising agents to limit wind-driven rain entering the core, particularly in exposed locations (See Vapour-open, capillary-closed treatments and finishes, shown here). These treatments are non-reversible

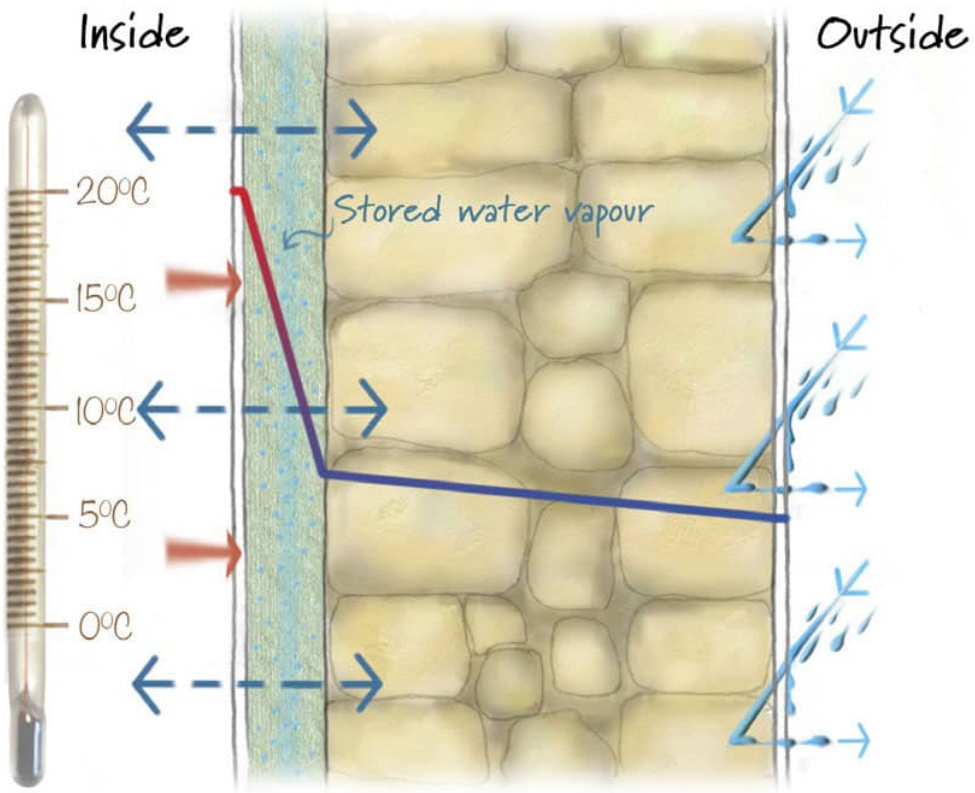
and, as such, should be regarded with extreme caution. Some formulations can reduce, if not stop breathability, trapping moisture and causing the breakdown of softer materials. It may be better to consider a rainscreen type of cladding or a breathable render as an alternative.



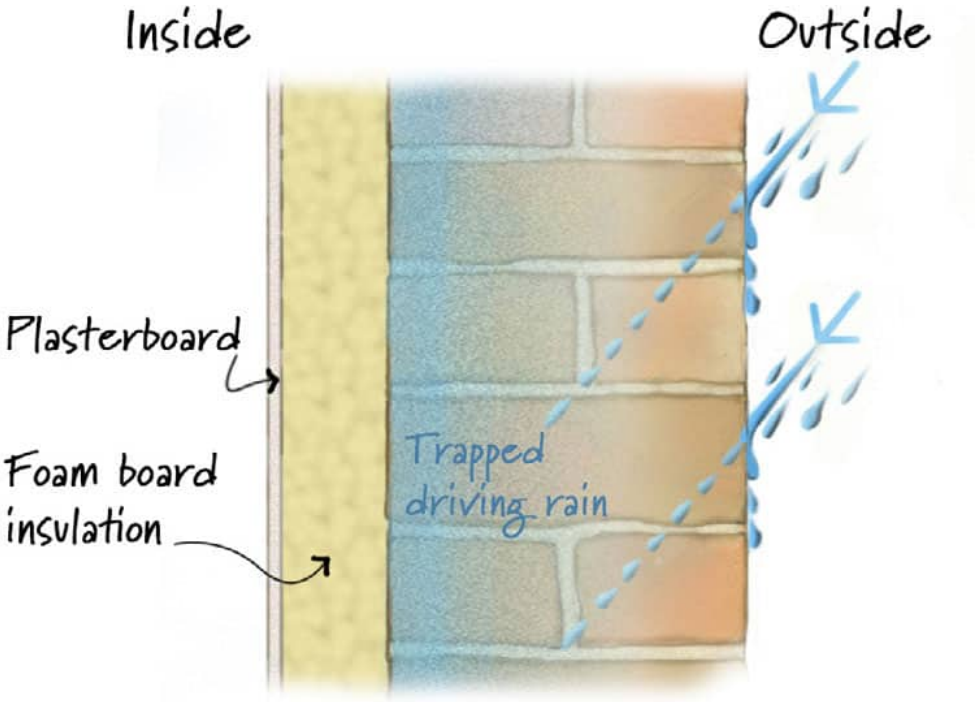
Non-breathable, or non-moisture-buffering internal wall insulation such as foam board or insulated studwork relies on an effective VCL. The foil face of a foam board will act as a VCL, provided it is taped at the junctions. In theory, this will stop water vapour from entering the wall and coming into contact with the cold masonry behind.



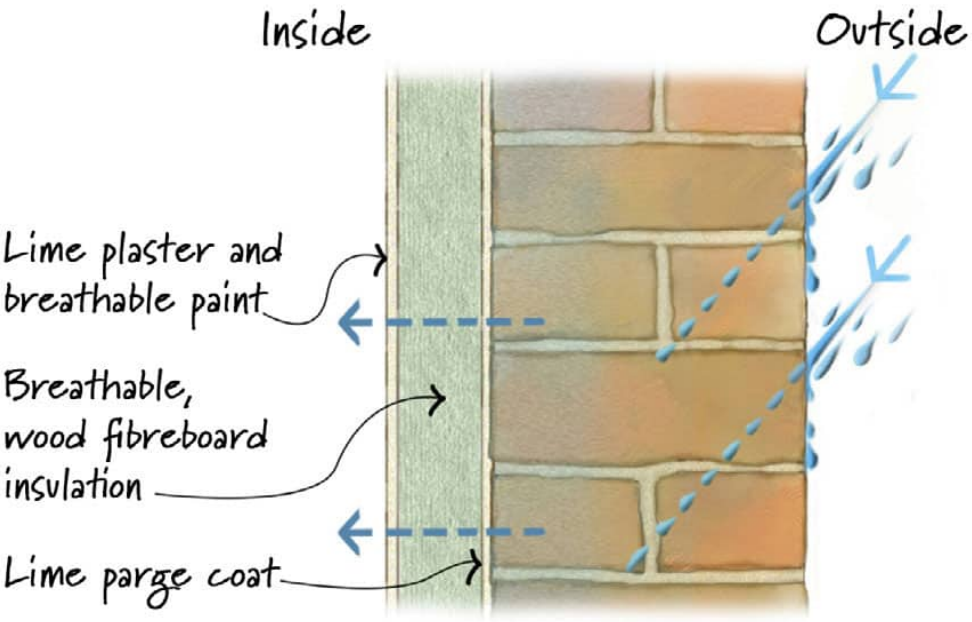
Over-reliance on VCLs is risky when they are used in conjunction with a solid wall. In this instance, foam board insulation has been used. But poor fitting, or inadvertent breaches, can result in vapour passing through and condensing if dewpoint temperature is reached within the wall. This will cause interstitial condensation where it cannot be seen, and cannot escape.



Wood fibreboard is usually a better option for internal insulation on solid walls. Once plastered, an airtightness layer is created that resists vapour passing through. Unlike foam boards or mineral wool, its moisture-buffering properties allow it to store a certain amount of water vapour, stopping it from reaching the cold masonry and condensing. It also allows a degree of moisture movement and evaporation in both directions. When the internal humidity drops, the stored vapour can evaporate harmlessly back into the room. Too much water vapour would eventually cause saturation of the insulation and the formation of interstitial condensation.



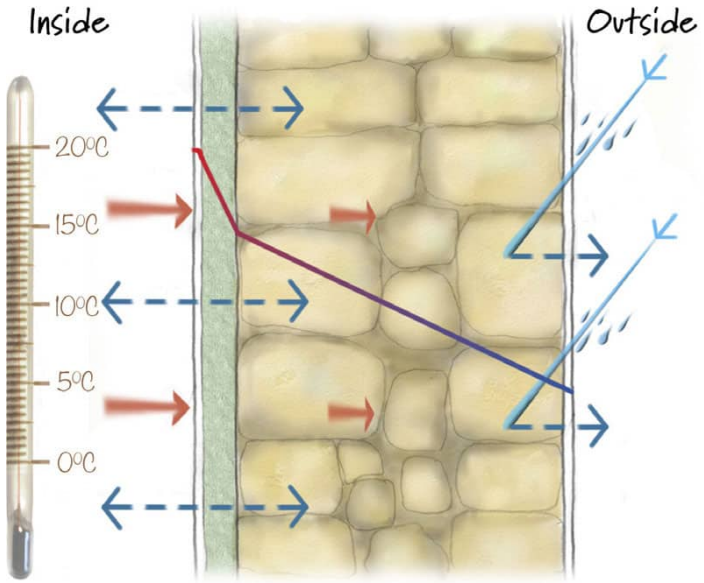
If wind-driven rain tracks through the wall, it can become trapped behind impermeable insulation such as foam board or a VCL.



Breathable insulation with good moisture-buffering properties, such as wood fibreboard, will wick wind-driven moisture away from the masonry and allow it to evaporate into the room.

Less is more

If the wall is generally dry and well maintained, but exposed to high levels of driving rain, it may be possible to add a limited amount of breathable internal insulation. By using a product that gives a total wall U-value of no less than 0.4 W/m^{2}K, some heat flow from the internal environment will still pass through the insulation and raise the wall temperature just enough to prevent moisture build-up. This strategy will also push the dewpoint temperature closer to the outside face, where any interstitial condensation can safely evaporate to the external environment. Provided the insulation is breathable and a VCL is not present, any moisture close to the internal face will be able to evaporate back into the room in the event of moisture tracking across the core. These U-values do not meet the target values listed within the Building Regulations, but less insulation does ensure that 'The work should not... increase the risk of long-term deterioration...' as stated in Part L1B (See Building regulations, shown here). Before ordering or specifying an internal insulation product, ask the supplier to carry out a hygrothermal (condensation risk) analysis (See Analysis, shown here).



Better to be breathable

Carefully detailed breathable systems with good density and moisture-buffering properties offer a safer and more robust option than impermeable internal insulation on most solid walls. Where products such as foam board may trap moisture at the interface between the insulation and the cold wall, a material such as wood fibreboard or calcium silicate board, fitted against the wall, will store any excess water vapour from the internal environment. In situations where driving rain has tracked across the wall, dampness can

be wicked away and evaporated back into the room. No VCL is required, although certain wood fibreboards designed for this purpose contain a silicate layer that is a vapour retarder, discouraging moisture from the room entering the wall while still allowing it to breathe.

These exposed clifftop houses in Cornwall receive high levels of driving rain. Internal insulation could be a risky strategy in this situation.

Which houses are at risk?

Installing internal insulation comes with problems, some of which can be reduced or even overcome through careful specification and good workmanship. Certain buildings are at much greater risk than others, and internal insulation may be best avoided in the following situations:

- Buildings with inherent or unresolved damp problems.
- Houses in exposed locations with high levels of wind-driven rain.
- Masonry walls with high wicking characteristics that do not have breathable external renders or rainscreens.
- Thin walls such as those in historic timber-framed buildings, particularly those walls facing south west.

In such instances, where the core of the wall may already be damp, internal insulation can exacerbate the problem, particularly non-breathable systems or those incorporating a VCL. If internal insulation is added, it separates the masonry wall from the internal heated environment and, without heat flow across the masonry, the mechanisms for drying out the core become more limited.

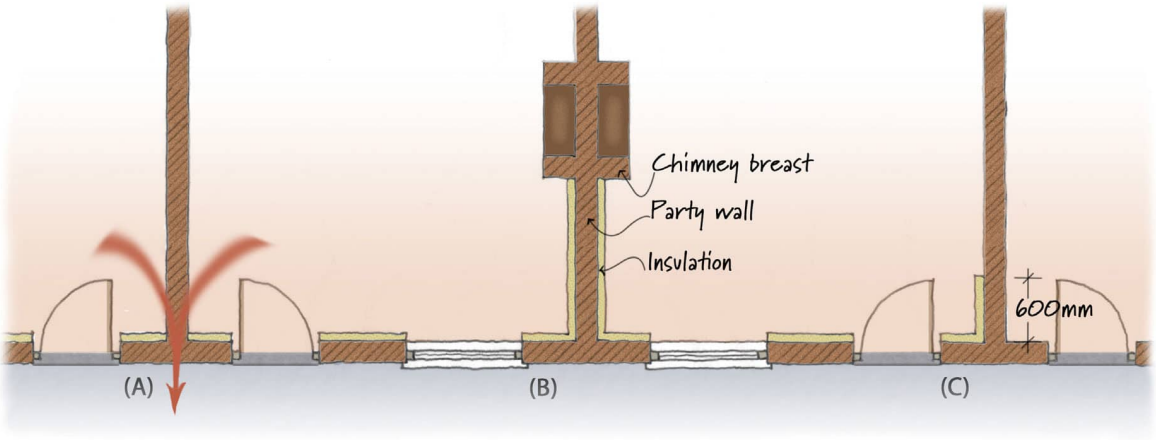
Embedded joist ends

One of the greatest risks of internal insulation is future decay to embedded joist and beam ends and timber lintels due to an increase in the moisture content of the surrounding masonry. Many internal retrofits will stop the insulation at the floor or ceiling junction. This creates a thermal bridge at the masonry between the joists within the floor void, encouraging condensation at a particularly vulnerable point in the wall.

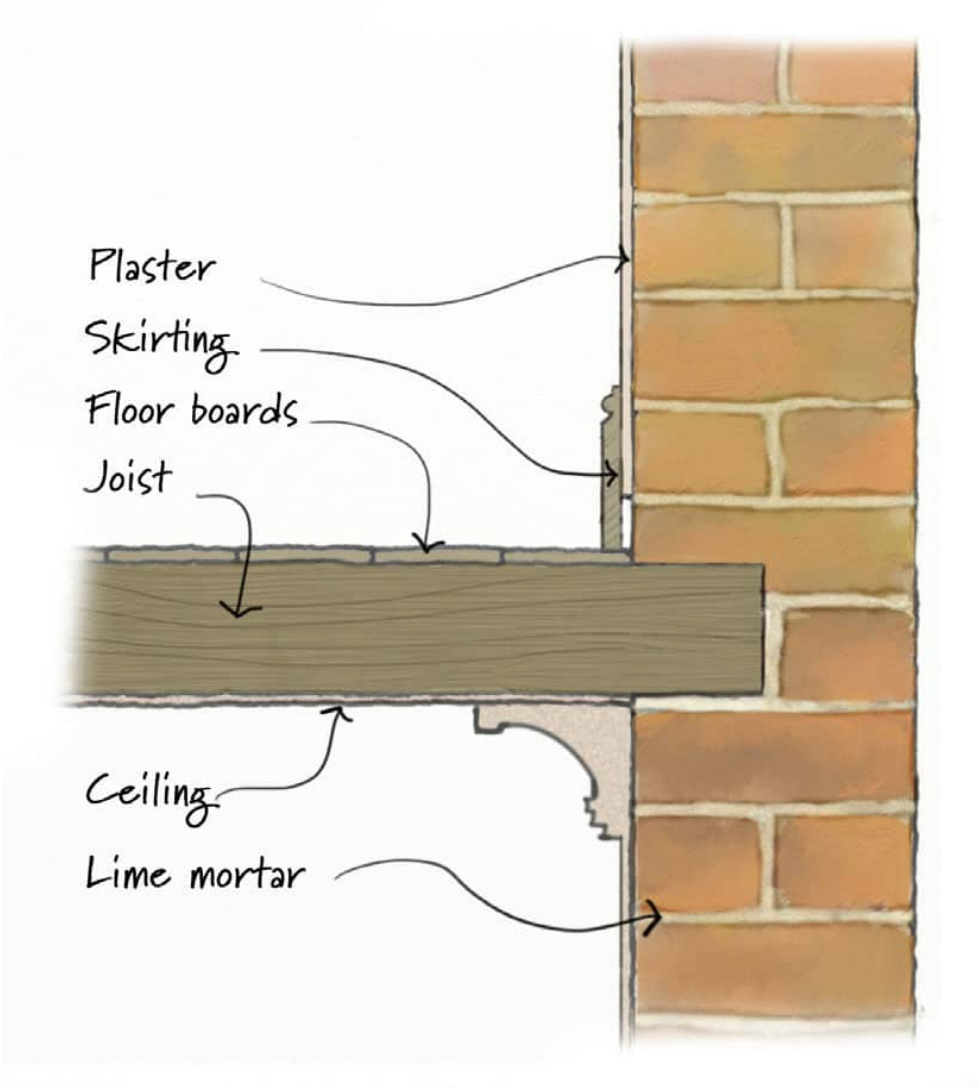
More rigorous retrofits usually involve lifting the floorboards at the edge of the room and continuing the insulation between the joists. Calcium silicate board is often used in this location due to its exceptional ability to wick moisture away. Some internal insulation systems recommend taping the junction between the insulation and the sides of joists. Airtightness around this junction is important to minimise water vapour passing through. It must not be forgotten, however, that the timber joist or beam will allow a certain amount of moisture to travel along it, meeting the cold masonry where the structural timber ends in the core of the wall.

Party walls

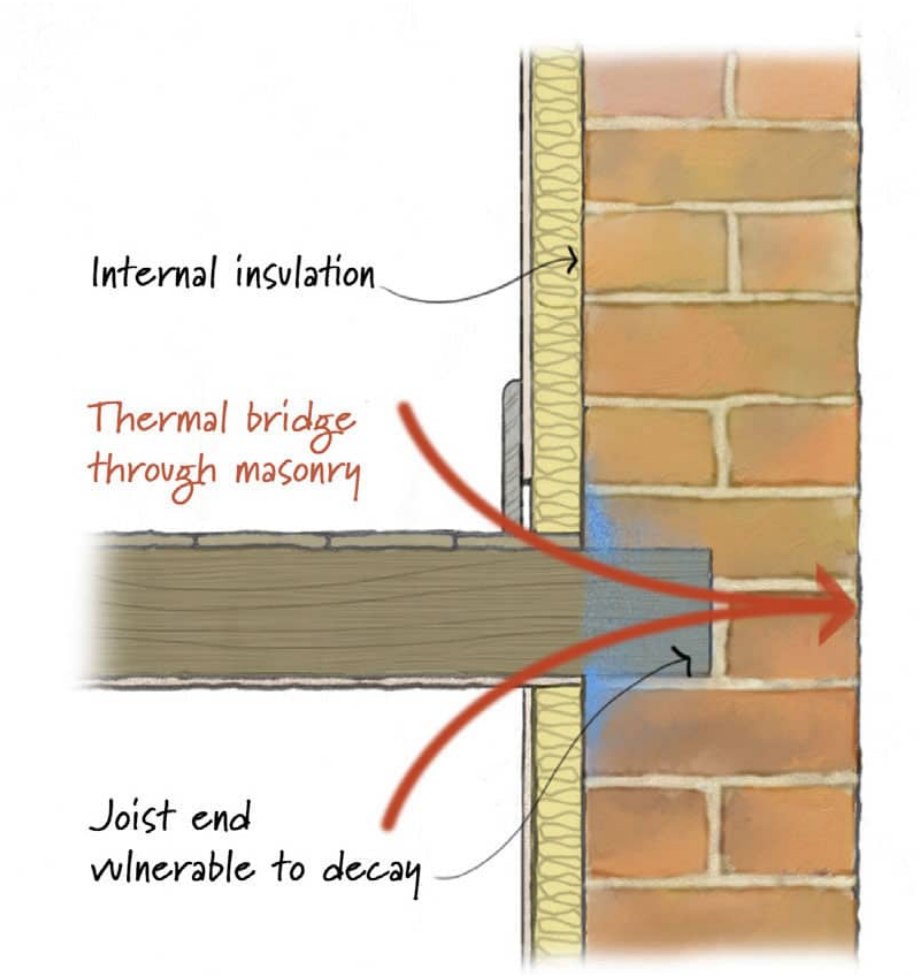
When adding internal insulation to a house that is attached to another, party walls have to be carefully considered. This plan of a terrace row illustrates three different situations: Junction A shows an insulated internal face that does not return along the party wall, creating a thermal bridge where heat can escape. Junction B shows the insulation returned all the way to the chimney breast, making it less visually obtrusive. Junction C shows insulation returned 600 mm along the party wall, creating an awkward step in the wall. Both B and C will reduce heat loss at the junction. A similar problem occurs when converting loft spaces, as the neighbouring space is often unheated. In such cases, it will be necessary to treat the party wall as an external wall and insulate it in its entirety.



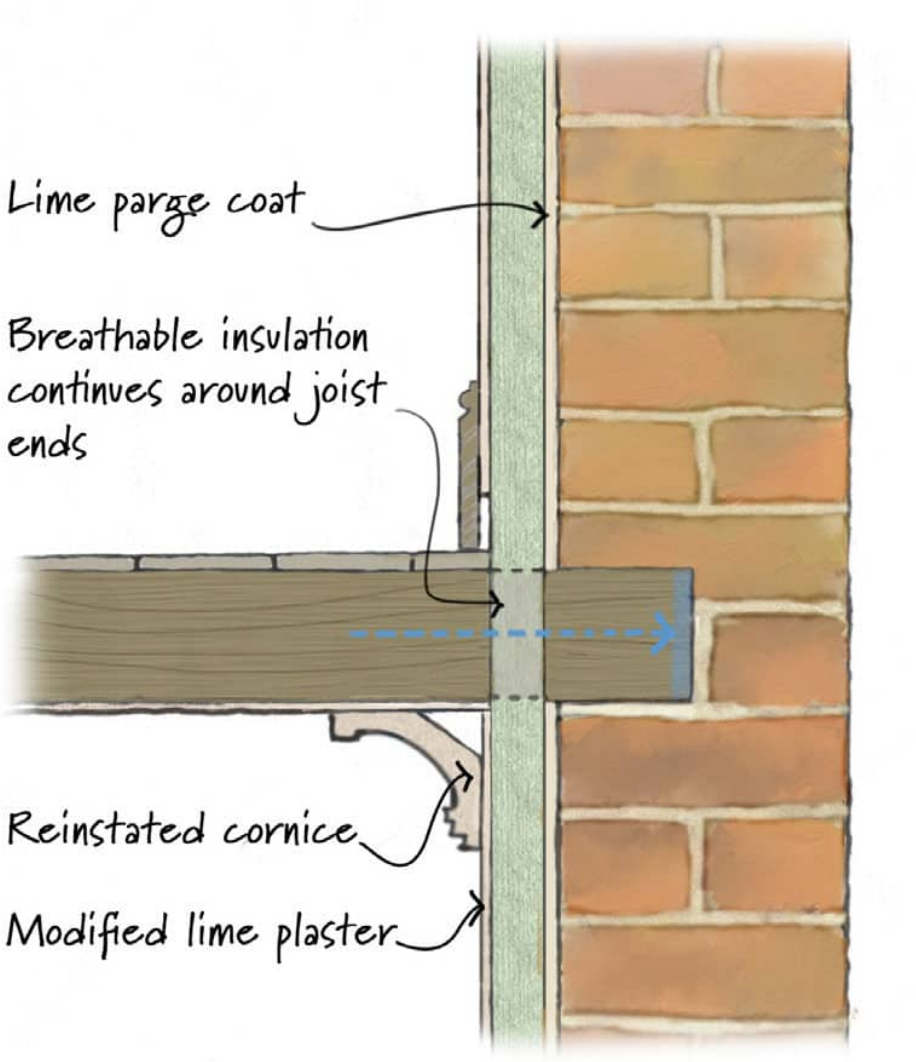
The longevity of joist and beam ends is dependent on minimising both condensation and driving rain, and keeping the wall as dry as possible. The long-term effect on embedded timbers is difficult to predict as there are so many complex factors involved. Monitoring is possible with moisture probes and may, in certain circumstances, be worth the additional cost. In a worst-case scenario, joist-end decay could go undetected behind internal insulation for many years until structural failure becomes apparent (See Monitoring, shown here).



Vertical section showing traditional wall construction with timber joist ends set into the masonry of the external wall.



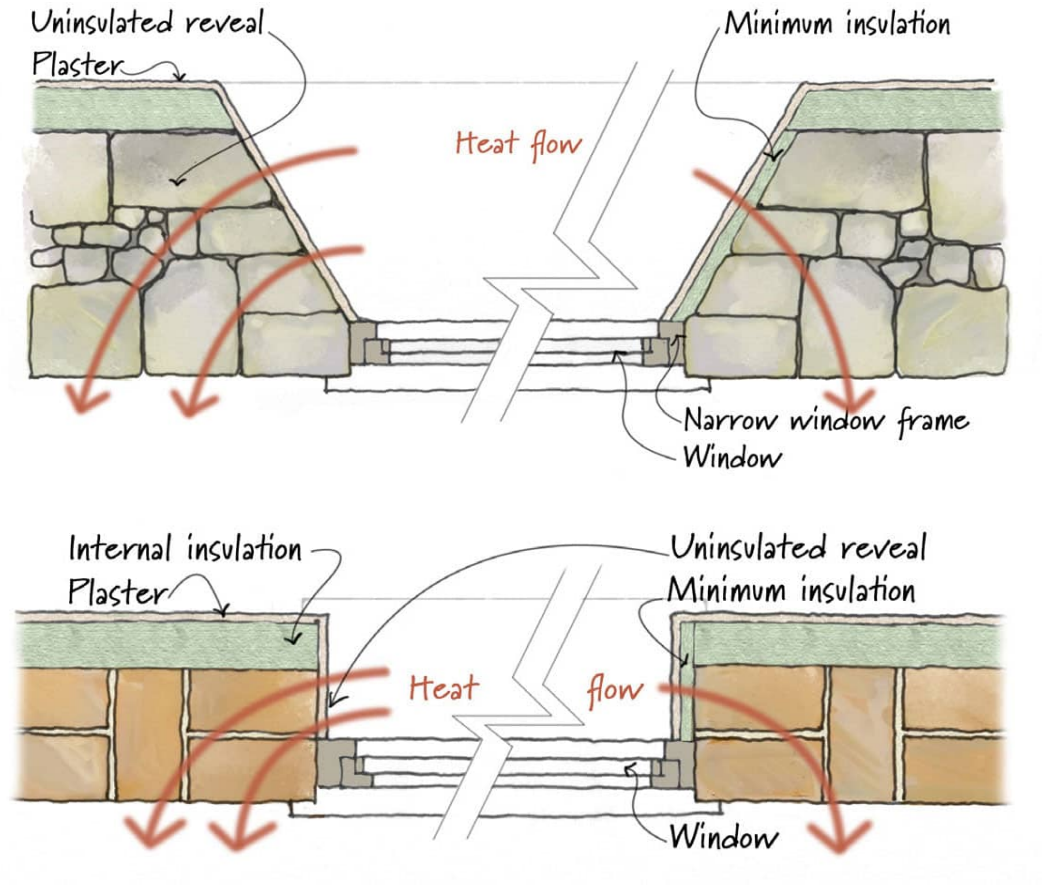
Internal insulation often stops at the floor and the ceiling, leaving a thermal bridge in the masonry between the joists. This will attract condensation and may rot timber joist ends.



More rigorous internal insulation systems recommend lifting boards and cutting back the ceiling to continue the insulation around the joists.

Window and door reveals

When walls are insulated on the inside, the treatment of window reveals is problematic. If left uninsulated, they can act as a thermal bridge, yet the thickness of the window frame usually limits the insulation that can be fixed to the reveal. The diagrams below show uninsulated reveals to the left, where heat loss is at its greatest. The reveals to the right have a thin layer of insulation, reducing the thermal bridge. Remember to allow for the thickness of the plaster on top of any insulation. The head of the window will also act as a thermal bridge and needs to be considered. Where insulation covers over a wooden lintel, it may become vulnerable to changes in moisture content.



Internal insulation: key issues

- Before opting for any internal insulation system, ask the company or professional involved about the risks of interstitial condensation. Request a hygrothermal analysis of the solution they are proposing and check this is not based on a Glaser diagram (See Analysis, shown here).
- Consider the amount of internal insulation that is safe to use, depending on the location and wicking characteristics of the wall. Houses in exposed locations should be insulated to a lesser degree, if at all.
- Breathable insulation products with good moisture-buffering properties are generally the most suitable for solid walls.
- Evaluate whether a VCL is appropriate for a particular situation and, if it is, make sure it is installed properly and without breaches.
- Detailing around joist ends requires careful consideration.
- Internal floor area will be reduced. This is a particular consideration in smaller houses and where maintaining passageway or staircase widths is crucial.
- Features such as skirtings, cornices and architraves will need to be removed.
- Original plaster and paint finishes will be hidden, and inevitably damaged or destroyed.
- Electrical sockets and switches, pipes and radiators fixed to external walls will need to be repositioned and detailed to avoid thermal bridging. In many cases, extensive rewiring and plumbing alterations will be required.
- Detailing around window and door openings must be meticulous to avoid thermal bridging and air leakage.
- Treatment of existing fireplaces needs to be carefully thought through.
- The effect of thermal mass in masonry walls is lost after internal insulation has been fitted.

Internal insulation can significantly reduce floor area and may result in characterless interiors.

BREATHABLE INTERNAL SYSTEMS

Numerous materials and systems are available for insulating masonry walls. There is no one solution for all buildings and what is used will depend on the breathability required, the space available, the cost and the thermal performance sought.

Preparing the wall

Careful preparation is key to successful internal wall insulation. A breathable system is dependent on getting back to a vapour-permeable substrate. If the wall is already finished with lime plaster and it is possible to strip any impermeable paint back to a reasonably sound surface, a good substrate can be achieved. Old wallpaper and paste should also be stripped, as it provides nutrients for mould growth.

Any gypsum plaster on the wall should be removed, as it breaks down when it gets damp, and cementitious and other waterproof plasters are also incompatible. If removing gypsum plaster, there are strict rules regarding its disposal due to the release of hydrogen sulphide gas.

Where the wall surface is uneven, a ‘parge coat’ of lime plaster is applied. This has a number of advantages:

- It fills cracks and holes, minimising air leakage.
- It provides a moisture buffer to the wall surface, absorbing any vapour or condensation at the interface with the cold masonry.
- It offers a flat and level plane on which to fit insulation boards, thus eliminating pockets of stagnant air on the cold side of the insulation that would be susceptible to mould growth.

It is important to use a non-hydraulic lime for maximum breathability. This needs to carbonate fully and dry before insulation is fitted over the top. A thin 10 mm parge coat over brickwork can dry within days, but thicker coats may need weeks to dry in the colder months.

Wood fibreboard

A number of manufacturers offer slightly different wood fibreboard products and systems, so shop around and follow the technical specification. Wet-processed boards are recommended for internal use (See Wood fibre, shown here).

Installing breathable systems

Step 1: A parge coat is applied to the inside face of the wall to prepare the surface for internal wall insulation.

Step 2: Once the surface has been prepared, the wood fibreboard can be applied directly. Choose a tongued-and-grooved system for ease of fitting and better vapour control. The board can be cut using a circular saw.

Step 3: A purpose-made breathable adhesive is applied to the rear of the board and combed ready for application to the wall.

Step 4: The board is pressed against the wall and locked into the tongue and groove of the adjacent boards.

Step 5: The board is gently tapped with a mallet to ensure it is securely fixed in place.

Step 6: Some wood-fibre systems have an integral top layer of dense fibreboard that is designed to take plasterboard fixings, shelves and wall cupboards. In this instance, the boards are mechanically fixed to the wall using a countersunk screw.

Step 7: Plasterboard can be dry-fixed directly to certain wood fibreboards and skimmed.

Step 8: For a more traditional finish, wood fibreboards may be plastered directly with a lime-based material. Note: this system has been mechanically fixed to the wall with non-thermal-bridging screws and washers.

Step 9: When plastering directly, the first coat of lime plaster is combed through and a fine plastic mesh is applied over and gently pressed in. This strengthens the plaster layer to minimise cracking, and forms a breathable but effective airtightness layer.

TOP TIP: SOCKETS BOXES

Most wet-processed wood fibreboards are made up of 20 mm layers, so come in thicknesses of 40 mm, 60 mm, 80 mm and other multiples. If installing socket boxes to finish flush with the wall, choose a shallow box of 40 mm depth. Provided your wood fibreboard layer is 60 mm or more, it is possible to scoop out the top two layers, enough depth for a socket box, while still leaving a layer of insulation behind the box. This will minimise thermal bridging.

Cork board

Used in a similar way to wood fibreboard, cork board is bonded to the wall with breathable adhesive. Cork behaves slightly differently to wood fibreboard. It is highly vapour-open, but is not as moisture-buffering or capillary-active. It is less susceptible to decay in damp situations, such as below ground. Cork does not come with a tongued-and-grooved edge, making it more difficult to fix to the wall.

Calcium silicate board

Highly capillary active and vapour open, calcium silicate board has the ability to wick moisture away from damp areas. It is primarily used as an alternative to wood fibre in situations where moisture may be an issue, or where there is concern over driving rain. As a mineral board, as opposed to an organic material, it is mould inhibiting and does not decay. It is also non combustible and pest resistant. Calcium silicate board may be ideal for certain situations, but it does not perform as well thermally as cork or wood fibre, and is several times more expensive.

Calcium silicate board is applied using adhesive.

Spray-applied hemp

Internal walls may be sprayed at low pressure with a hempcrete mix. This can be applied to a vertical surface in thicknesses of up to 120 mm in a single layer, giving excellent moisture-buffering and thermal performance. As well as being quick and economical, spray application offers the advantages of better adhesion, quicker drying times and minimal shrinkage.

Corkboard insulation installed with an appropriate thermally broken fitting to avoid the problem of thermal bridging.

EXTERNAL INSULATION

External insulation is technically a better option than internal insulation in most situations (See Inside or out?, shown here). It is like wrapping your body in a thick duvet to keep all the heat inside. By keeping the mass of the wall warm, the risk of interstitial condensation is virtually eliminated as the temperature within the wall does not reach dewpoint. (See Condensation and dewpoint, shown here). External wall insulation also exploits the thermal mass of a masonry building by storing heat generated internally and

re-releasing it as the internal temperature drops. It is important to select an insulation product that is more breathable than the wall onto which it is fixed, so that any moisture within the masonry can be evaporated to the outside.

External wall insulation may be a good option where the building has a rendered or clad facade, as it can potentially be insulated and re-rendered or re-clad without too much change to its appearance. This is not the case if the house is constructed of decorative brickwork, has fine detailing or has an exposed timber frame with infill panels. External insulation can be particularly unsatisfactory if the building is part of an unspoilt terrace where the architectural cohesion of the rest of the row would be destroyed by changing the outside of a single dwelling.

External insulation: key issues

- Always resolve any existing damp problems before insulating, otherwise residual and continuing dampness will be trapped inside the wall.
- Even if the building appears dry, any insulation system to a solid-walled structure should consider breathability to allow the movement of moisture through the wall.
- If the building is in an exposed location, it may be advisable to use a vapour-open, capillary-closed finish to minimise the absorption of driving rain. Alternatively, consider cladding, tile-hanging or lime roughcast.
- As the building is likely to last longer than the insulation that is fitted, consider reversibility and ensure it can be removed with minimal scarring to the building.
- By insulating on the outside, the thickness of the wall will increase. This will almost certainly mean an adjustment to roof details such as at the eaves and verge to provide a wider overhang.
- If the rafters need to be extended to accommodate the extra thickness of the wall, check that they will not obstruct outward-opening windows or doors.
- The added thickness of external insulation may result in the walls oversailing property boundaries, or alleyways and footpaths between buildings becoming too narrow. This can pose legal, planning and access issues.
- Details around window and door openings need careful consideration to ensure a neat finish and continuity without any steps, gaps or thermal bridging.
- Any insulation to window and door reveals should allow their frames to be removed for repair or renewal in the future.
- The position of window frames may need to be altered to avoid the window being set back too far within the facade.
- Gutters, downpipes, soil pipes and cables running down the face of the wall must be removed and reinstalled.
- Rainwater gullies at the base of the wall may need to be re-sited.
- Boiler flues, overflow pipes and condensate pipes might have to be extended.
- Carefully consider any detailing to parapets and chimneys.
- Where decorative front elevations preclude external insulation, consider external insulation to the other elevations, such as end gables and the rear of the building.

Detailing around windows will need to be considered when planning external wall insulation. Here, a deeper cill has been fitted, and linings to the sides and top of the opening are designed to finish flush with the final render.

This house was re-tiled prior to fitting external wall insulation. The opportunity was taken to extend the rafter feet so that they would project beyond the thickness of the new insulation and shed the rainwater clear of the wall.

External insulation must be carefully thought through, as it will impact on various details. Here, the rear of a typical terrace is shown before and after insulation. The insulation has been brought down to incorporate the majority of the wall, but stops short as an extension is to be added to the house in the future. Note that traditional wooden sash windows have been reinstated.

BREATHABLE EXTERNAL SYSTEMS

When used externally, wood fibreboard cannot be taken down to the ground due to its wicking characteristics. It can be stopped just above ground level on a metal render stop, but this is aesthetically an unsatisfactory way of finishing the base of the wall. It would also require internal insulation along the base to avoid thermal bridging. Most systems recommend the use of an external plinth board, manufactured from expanded polystyrene. This is taken down below ground level and at least 300 mm above. Specially modified lime render is then applied to both wood fibre and plinth board, with a fine mesh pressed in to minimise cracking. The plinth board does not generally compromise the overall breathability of the wall as moisture is

free to evaporate around it, but this detail can spoil the wall's traditional appearance if it is not carefully thought through.

The roof to this unlisted nineteenth-century brick house has been adapted to allow for thick wood fibreboard to be fitted. The flat plane of the brickwork has provided an ideal substrate for fixing, but the bricks would be badly scarred if the decision was ever taken to remove the insulation.

1 & 2: When walls are true and square, wood fibreboards are fitted in easy stages.

3: In this instance, the walls are out of plumb and a much thinner board was employed so that it could flex to fit. Where the boards meet at the corner, a rasp was used to trim the hard edge, allowing the final plaster coat to be rounded, in keeping with the building.

4: To provide a stop for the plasterwork, the cills were extended and side linings and pentice roofs were fitted around the windows before the wood fibreboard was installed. These were screwed in from the face to enable them to be replaced in the future without removing the insulation. This will not suit all styles of window but it was a traditional feature for many casements to shed water clear of the cill. It may be worthwhile fitting lead over the pentice roofs on southwesterly elevations to prolong their life.

5: A chalk lime render with a plastic mesh was used over the wood fibreboard, rather than the finish recommended by the board manufacturer. The two materials have adhered well in this instance and have provided a more traditional appearance to the building.

INSULATING LIME PLASTERS AND RENDERS

Numerous insulating lime plasters and renders are available. Many claim to be breathable or microporous but, to ensure compatibility with a solid-walled structure, aim for a product that is lime based, usually developed by a lime-plaster supplier with experience in the field. If you are uncertain about a particular supplier, ask them to provide a value for vapour permeability or a Declaration of Performance stating the strength of the product.

Insulating lime renders and plasters are extremely useful in certain situations. They are ideal for thick rubble-stone masonry walls where a 25

mm internal layer will create a more thermally responsive surface, especially where an intermittent heating regime is employed. They can be applied thickly, and most products have minimum shrinkage. This is ideal for dubbing out masonry; the nature of the material allows plaster to be sculpted with rounded corners and gentle undulations. Aesthetically, this is often far more in keeping with a vernacular building than the flat planes and hard corners that result from a boarded system.In terms of thermal performance, insulating lime plasters and renders compare poorly to breathable insulation boards. If you can increase the thickness of a solid brick wall by 50 mm, it would usually be better to use a 40 mm board with a 10 mm plaster finish, rather than apply a 50 mm layer of insulating lime plaster.

Products are available in both non-hydraulic and hydraulic lime forms mixed with various types of insulating fibres or granules. Non-hydraulic lime insulating renders can be more vapour permeable than hydraulic limes and therefore may be more suited to soft and weak substrates as they offer greater breathability. They take longer to set as they rely wholly on the absorption of CO_2 and will be more vulnerable to frost, limiting the times they can be used and the thickness that can be applied. Non-hydraulic lime renders sometimes contain ‘pozzolanic additives‘. These are designed to speed up the set, but they can impede breathability if added in large quantities.

More commonly, hydraulic limes form the base of insulating renders. These come in a powder form and need to be mixed with water on site just before use. Always ask what strength of lime is present, and avoid anything greater than NHL 3.5 (See Using lime, shown here). Note that, while a straight mix of NHL 3.5 and sand may be too hard for many sub-strates, when it is mixed with a lightweight aggregate to form an insulating plaster, its vapour permeability will be much greater and its crushing strength much lower. Reputable suppliers should be able to answer tricky questions regarding the suitability of a particular product for a given situation.

Foam glass beads are commonly used as an insulating aggregate, as they have high crushing strength and low water absorption. Lightweight and highly porous, the beads have a closed-cell structure, and can be used in

situations that may be exposed to damp. The mix tends to be more impact resistant than some other insulating products and therefore more suitable in certain locations.

Hemp fibre is another common additive that gives lime plaster an insulating property. Generally recommended for internal use, it provides a beautiful texture in a vernacular building. Its organic nature is vulnerable to mould growth if, for any reason, the insulating plaster is applied too thickly and fails to carbonate, or if the wall is damp. Carefully follow the manufacturer’s instructions regarding the maximum thickness of each coat and ensure that each layer has properly carbonated before the next is applied. Hemp-based plasters have minimal shrinkage.

Perlite granules have been blended with a weak hydraulic lime to create this insulating plaster.

An insulating plaster is being applied internally to a wood fibreboard for additional insulation to a timber-framed house. This gives a more undulating, traditional finish to the room, but check that the product is compatible with a board substrate.

Cork-lime insulating renders are also gaining popularity. As with many insulating plasters, they tend to be very soft, and therefore need to be finished with a harder and more durable top coat. But they remain rather vulnerable in areas that are subject to impact or likely to be knocked, such as external corners.

With insulating plasters, other additives may be present depending on the product – for instance, cellulose, starches and gums, which act as natural

swelling polymers to reduce shrinkage. Depending on the system used, the finish coat may contain hydrophobic agents to reduce water absorption. In order to maximise breathability and allow any moisture within the fabric to escape, it is important to finish the external render surface with a vapour-open texture, rather than a smooth, closed texture. This is usually achieved by using a plastic or wooden plasterer's trowel or float, rather than a metal float.

Insulating plasters and renders can usually be applied to a maximum thickness of 25 mm in one application. Additional layers may be added to build up the desired thickness and improve thermal performance as required. It is important to allow each coat to dry before the next application and to carefully follow the manufacturer's instructions.

Applying a cork-lime insulating render to a masonry wall.

These walls have been drilled for cavity fill and the holes have been plugged.

INSULATING CAVITY WALLS

Although we associate cavity walls with modern buildings, the first cavity walls date back to the mid-nineteenth century or even earlier. These were designed not for insulation purposes, but to resist rainwater penetration. The practice of retrospective cavity fill has become widespread and is generally regarded as a cheap means of improving the U-value of a cavity wall. It is carried out by drilling a series of holes, about 22 mm in diameter, every metre across the external wall horizontally and vertically. The installer then blows in either loose-fill polystyrene bead, mineral wool or a foam insulant.

Insulating lime renders and plasters: what to ask

When selecting a product, ask the manufacturer the following questions:

- Is it lime-based? If so, is it hydraulic or non-hydraulic?
- What is the insulating additive?
- What is its vapour permeability?
- How is it finished – can a traditional limewash be used?
- Is it suitable for your particular substrate?
- Is it easy to apply?
- What is its shelf life?
- How thickly can it be applied in a single application?
- How long before a second coat can be applied?
- Is it suitable for internal and external use?
- How do you avoid failure?

Cavity wall: key issues

- Make sure you use a qualified and registered installer, who will carry out a survey before the work starts, to inspect the condition and suitability of the cavity and wall ties.
- If you have a suspended timber floor, ensure that the installer sleeves any airbricks prior to installation and check that they remain unblocked to provide essential ventilation to the timber structure.
- Ask the installer how the holes through which the insulation has been installed will be filled after the work has been completed; poorly skilled installers may leave unsightly blemishes across the face of the wall.
- Resolve any penetrating damp problems before attempting cavity insulation.
- Do not attempt cavity fill if your cavity is less than 50 mm.
- Seek impartial advice if your walls are subjected to extreme wind-driven rain conditions, as cavity fill may result in damp penetration to the internal wall (See Location, location, location, shown here).
- Bear in mind that foam insulation adheres to surrounding masonry and is very difficult to remove, so is essentially non-reversible.

- If the cavity fill is poorly executed, it can leave empty pockets that will become thermal bridges, with condensation leading to black mould forming on the internal face.
- Because the outside leaf of the cavity is colder and damper, any metal wall ties may be subjected to accelerated corrosion.
- Avoid cavity fill if your wall contains an outer leaf of absorbent soft brickwork, as this could lead to penetrating damp from rain being absorbed by the cavity insulation.

Lath and plaster linings

In Scotland and parts of northern England, it was common to line the inside face of external walls with a timber studwork frame clad in wooden laths and coated with lime plaster. Lath and plaster was commonly used to form ceilings and internal partitions but here, as an early form of dry lining, it continued into the twentieth century. It created a cavity (normally about 50 mm) between the external masonry and the inner studwork to give additional insulation. Trials have been carried out to improve the thermal performance of lined walls with blown insulation materials. Bonded bead and loose cellulose has been shown to give a reasonable reduction in U-value. The techniques are similar to those used for conventional cavity walls.

Cavity or solid?

You can tell a lot about a brick wall by looking at its bonding pattern. A cavity wall will have a ‘stretcher’ bond, where all the bricks are laid with the long side facing outwards. There are usually two skins or leaves of brick joined together with wall ties, typically separated by a 50 mm cavity.

As the name implies, solid walls have no cavity, just two or three bricks laid side by side. The wall width is generally 9 or 131/2 inch (225 or 338 mm) and can be identified by end-on or ‘header’ bricks in the bonding pattern. These are bricks laid at 90 degrees to the wall, keying through to the inside face. The appearance of headers can sometimes be misleading, since high-quality modern brickwork may replicate the look of traditional brick bonds using ‘snapped’ headers – half-bricks in a cavity wall construction.

Stretcher bond in a cavity wall.

Flemish bond with glazed headers in a solid wall.

Loose-fill insulation being blown into the gap between lath and plaster and external wall.

A sixteenth-century timber-framed house following extensive repair and sensitive thermal upgrading. Modern infill panels have been replaced with hemp and lime.

INSULATING HISTORIC TIMBER FRAMES

With their exposed oak frames and infill panels of wattle-and-daub or decorative brick, timber-framed buildings are among the most energy-inefficient of all traditional building types. This is particularly the case if the timber frame is exposed both internally and externally. Heat loss through the thin walls, coupled with gaps between panel and frame, can create cold and draughty living environments. This makes them a prime target for inappropriate retrofit solutions that trap moisture and leave the frames and wattle panels vulnerable to decay and structural collapse.

Wattle-and-daub as a material performs well in terms of energy efficiency but, in a timber-framed building, the infill panel is generally just 100 mm thick, with a typical U-value of around 2.1 W/m2K. If the infill panels are made of brick, the thermal performance is even worse, approaching a U-value of 2.5 W/m2K.

There are a number of approaches that you can take to mitigate the problems of an energy-inefficient timber-framed building. None is simple and they would usually be part of a more extensive programme of repair.

Before embarking on any alterations to the external walls, get a condition survey of the structure by an experienced professional and understand how the frame works. Airtightness and thermal imaging tests are particularly useful with timber-framed buildings to gain a better understanding of how the building is performing before works commence.

Before the hemp lime panel has fully cured, remove any shuttering and press back the edges to allow for the thickness of plaster to butt against the side of the timber frame.

Hemp and lime is ideal for casting replacement panels in timber frames, particularly in awkward-shaped holes.

Replacement panels

If you have wattle-and-daub panels, they are likely to be hundreds of years old and their preservation should be paramount. Handmade brick panels became common from the seventeenth century onwards but, frequently, timber-framed buildings contain modern brick or even blockwork panels, with recent plaster finishes. Where the latter applies, consider replacing them with a more compatible material such as hempcrete. This is the modern equivalent to wattle-and-daub, and can be cast in situ or spray applied to fit the space perfectly. The hempcrete mixture forms a lightweight material, with breathing characteristics that are compatible with the timber frame. Hempcrete is not straightforward to mix or cast, and mistakes are easy to make. If you are not using a specialist contractor, always employ an on-site trainer to demonstrate the operations involved.

Alternatively, wood fibreboard can be used to make infill panels. Generally, an 80 mm thick board will suit, set back slightly from the face of the frame to allow for plaster.

Covering the frame

Where the timber frame is visible externally, consider applying a lime render right over it. You may be horrified at this suggestion, but there is a

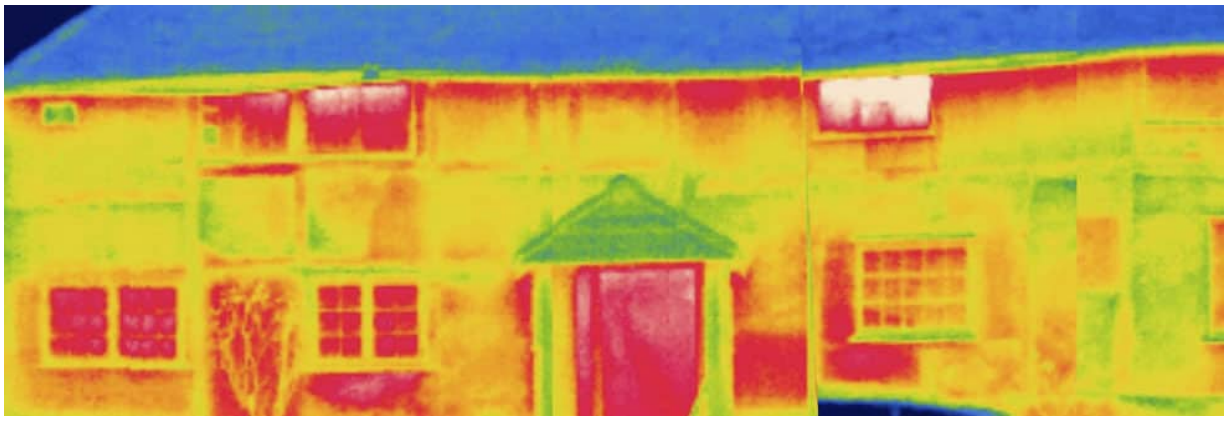
good chance that the building was rendered at some point in the past and has been stripped only recently. Look at old photographs from the local record office and study the earlier finishes. Obviously, this solution will not be appropriate if the frame is exceptional and was designed to be on show.

A lime render alone will not markedly improve the U-value of a timber-framed wall, but it will dramatically reduce draughts from the gaps around the panels while also protecting the frame from further decay. Ensure that it is a non-hydraulic lime mix, applied by experienced plasterers used to dealing with such buildings.

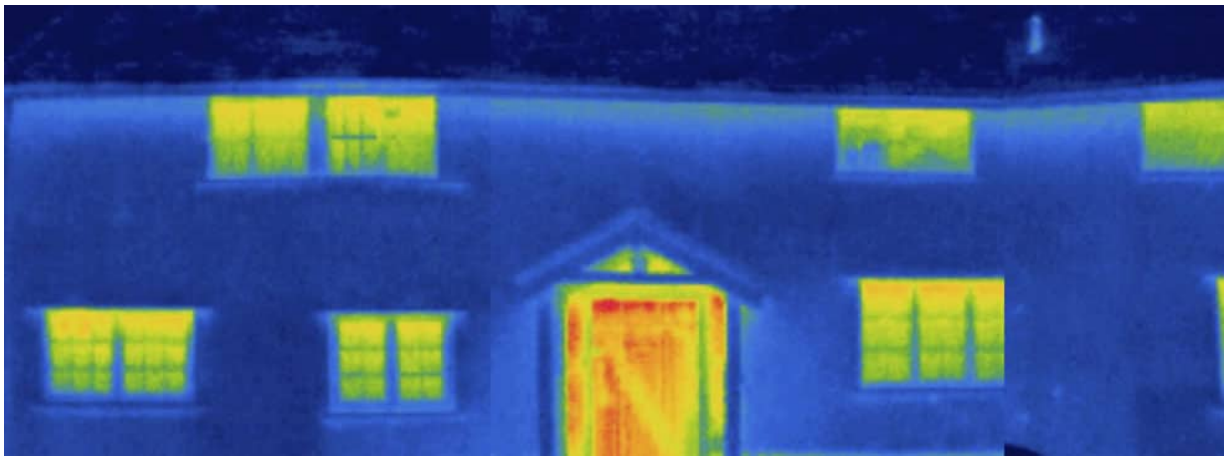
This timber-framed building in Oxfordshire was rendered historically, as shown in an old photograph of 1920.

In the 1970s, the lime render was removed and the infill panels were covered in a cement-based finish.

Listed building consent was granted to reinstate the chalk-lime rendered finish, over wood fibreboard insulation.



The thermal images show the timber-framed house before (above) and after (below) wood fibreboard insulation and chalk-lime render has been applied. The roof has also been insulated and secondary glazing added to the windows. The significant improvement to the overall energy efficiency of the building can be clearly seen.



The opportunity could be taken to apply an insulated render. Check the breathability of the proposed mix first to ensure that it is compatible with a timber-framed building. Alternatively, consider applying wood fibreboard over the external frame to provide both insulation and a suitable substrate for render.

External cladding may be a good option for certain timber-framed buildings in order to improve energy efficiency, depending on the historic significance of the frame and the local traditions. Weatherboarding or tile-hanging was frequently used in the past; adding either would allow the insertion of a breathable insulation board behind. If considering such a solution, always seek professional advice rather than go directly to a tradesperson. Such alterations need to be carefully thought through and properly detailed.

Internal insulation

Where neither the infill panels nor external appearance can be changed, the option is to insulate from the inside. Be aware that timber-framed buildings dating from the seventeenth century or earlier may contain wall paintings. Often they are found on early plasterwork behind layers of later paint, so seek advice and consent if necessary before covering over or disturbing original plaster. If they are not present or where, as is often the case, modern gypsum plaster has been applied, an insulating substrate, such as wood fibreboard with a lime plaster, could be a good solution (See Less is more, shown here).

08 | FLOORS

Floors have a big impact on the thermal comfort of our homes, as they can contribute to both draughts and considerable heat loss. Depending on the construction, it may be possible to upgrade the thermal efficiency of a floor through simple measures. The challenges are to avoid upsetting the building's moisture equilibrium or destroying its historic character.

The ground floors of old houses were of either solid or suspended construction. Solid floors consisted of compacted earth, often with stone flags, bricks or tiles laid directly on top. Suspended floors are more sophisticated and were formed of wooden boards nailed to a timber joist structure with ventilation beneath.

Over the last few decades, many beautiful old floors have been removed and replaced with a concrete slab and damp-proof membrane (DPM). Often this is totally unnecessary and a sound, dry, historic floor has been needlessly lost. Where damp is an issue, installing a concrete slab and DPM will often simply exacerbate the problem by pushing moisture up the walls. There are far better and more sympathetic ways of addressing damp-related problems.

The quest for energy savings, through improved insulation and airtightness, presents another major threat to surviving old floors and the danger of unnecessary loss. Before doing anything, understand what you have and look at ways of upgrading the floor to provide a thermally efficient solution using techniques that work with the character and breathing structure of the building.

BUILDING REGULATIONS

When ground floors are being replaced, they must comply with current U-values for new buildings. If existing floors are thermally upgraded, they are

required to meet a less stringent U-value under the circumstances listed shown here. Upper floors would not usually require insulation unless they form part of the thermal envelope, for instance, a room over an unheated garage or passage.

The regulations accept that compliance may not be possible if this would cause ‘significant problems in relation to adjoining floor levels’ – for example, if insulation would raise the level of the floor, resulting in a step at the edges or the need to trim the bottom of historic doors.

Beautiful old floors at The Landmark Trust’s Calverley Old Hall. The flagstone floor to the dining room **(above)** and wooden floor to the bedroom **(below)** add character to the historic

setting.

CHARACTER AND BEAUTY

Both solid and suspended floors will have accumulated a surface patina and have aesthetic and historic value. Stone flags, tiles or bricks rarely look the same when they are taken up and relaid, and they may be accidentally chipped or fractured in the process. Old floorboards display distinct joint and nail patterns, but damage is inevitable if attempts are made to lift them, so think hard before starting work, especially if the boards are wide or historically significant.

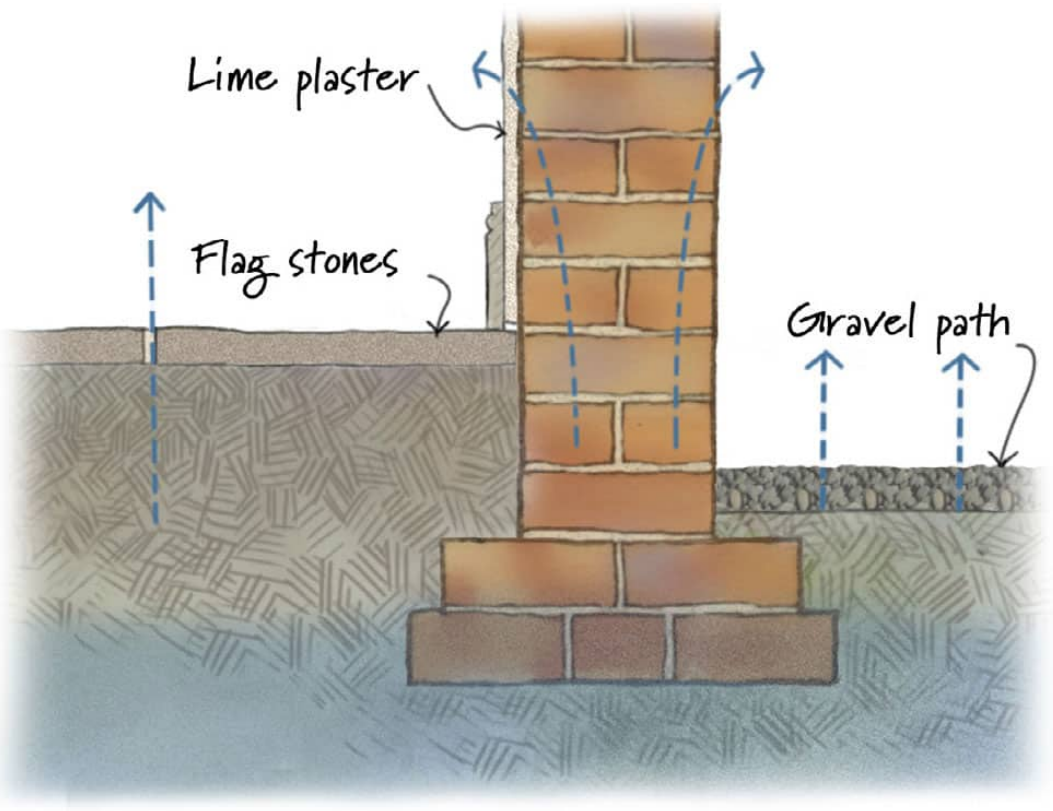
Consider the implications before adding insulation above an existing solid or suspended floor. Such actions have an impact on period features such as

skirtings and staircases, and doors may need to be trimmed. Low electrical sockets will also require adjustment. The overall room height will be affected and this may present real problems where doorways are already low. If only certain areas are being insulated, the step up presents a trip hazard so a ramp might be necessary. Where character and beauty are compromised, it may be better not to insulate.

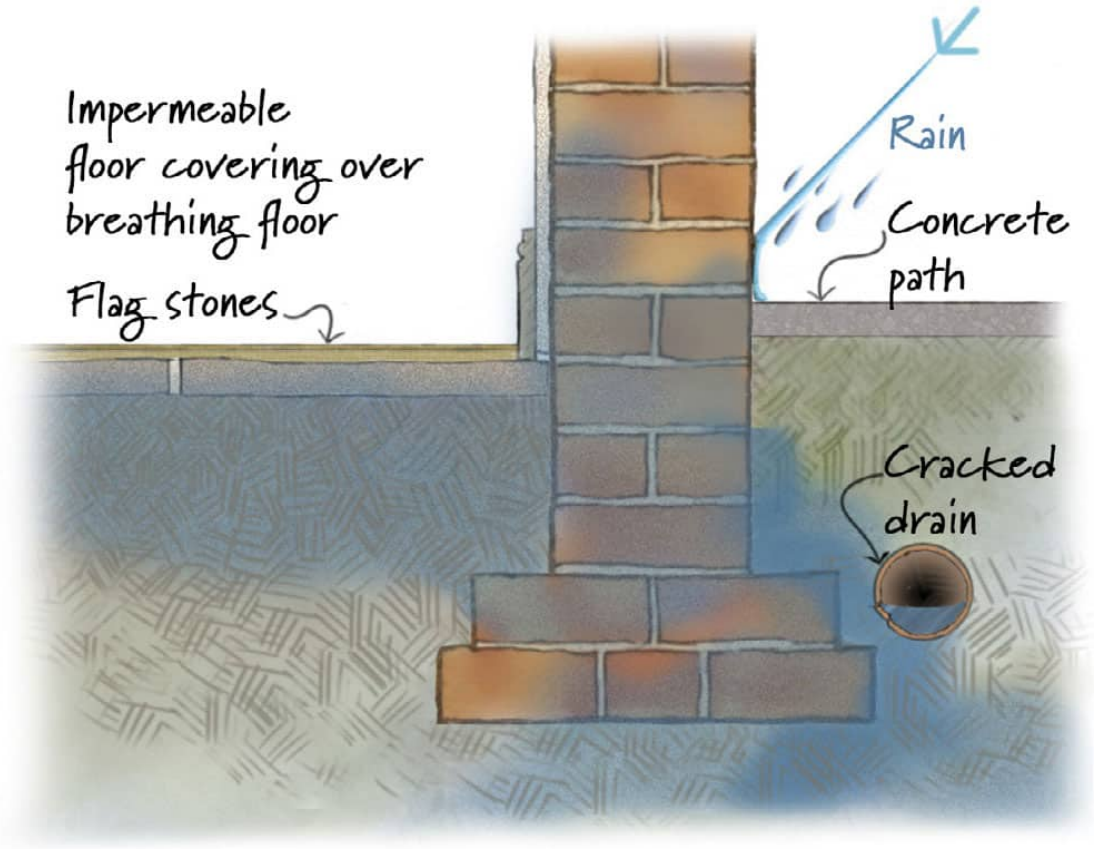
The floor of the room over this passageway will require additional insulation and draughtproofing to prevent excessive heat loss.

The character of old floors, such as these seventeenth-century flagstones, is invariably lost if they are lifted or disturbed.

Any insulation that raises the level of a floor will impact on doors and skirtings.



Traditional solid floors do not incorporate a DPM. Any dampness in the earth can easily evaporate through permeable junctions and finishes, as indicated by the blue dotted lines. The external ground level should be kept below the internal floor level to stop damp tracking across.



If external ground levels are allowed to rise above the internal floor level, moisture will track across, causing dampness in the floor and the base of the wall, as well as decay to skirtings. Cracked drains may result in localised dampness and concrete paths will prevent evaporation. If impermeable floor coverings are laid, they will trap rising ground moisture beneath.

DEALING WITH DAMP

Before attempting to insulate a floor, remedy damp-related problems. If dampness is evident, thermal performance will be compromised and the living environment will be less healthy. Check that external ground levels are lower than the internal floor and ensure that rainwater gullies are working efficiently. Where there is a persistent damp problem, commission a drainage survey. This will indicate the position of pipes, their condition and any leaks. Also check mains water and central heating pipes, as well as soakaways close to the building.

Coir or sisal matting is an ideal finish for breathing floors.

SOLID FLOORS

Traditional ground floors usually consisted of bricks, tiles or flags laid on compacted earth. It was not uncommon to incorporate a bed of sand or lime mortar to level them and prevent them from rocking. Even where the earth beneath appears dry, floors tend to evaporate imperceptible quantities of water vapour rising up from the ground below. This escapes between the gaps in the flags or tiles, or through the surface of unglazed bricks. Provided the floor is free to breathe, a healthy internal environment will readily dissipate this tiny quantity of moisture without it causing a problem.

Fitted carpets, rubber-backed underlays and vinyl laid on breathable solid floors will trap moisture, causing the floor to sweat and potentially leading to mould growth. Removing the floor covering generally cures the problem. If salts become evident during the drying-out process, they should be vacuumed off (See Designing for flooding, shown here).

Bubbling paint at the base of a wall may indicate a concrete slab and DPM that is forcing moisture to the perimeter.

Concrete floor slabs

In recent decades, refurbishment has usually resulted in old floors being taken up and replaced with a concrete floor slab. Since the 1970s, these slabs usually incorporated a DPM in the form of a plastic sheet laid between the earth and the concrete. While the intention of installing a DPM was to prevent damp from rising, it often simply pushed the moisture from under the floor to the outside walls, creating a rising damp problem at the perimeter of the room. This is frequently misdiagnosed and incorrectly treated when the floor itself shows no sign of failure. Earlier concrete slabs

were laid without a plastic DPM. They were sometimes coated with bitumen to the top surface to resist moisture, but this often failed and allowed moisture to rise. In such cases, dampness may be present across the entire floor surface, particularly where a non-breathable floor covering has been laid above.

Dampness associated with concrete slabs is even more likely where the floors have been excavated and lowered to accommodate the thickness of the concrete slab, or to increase the floor-to-ceiling height within the room. By digging further down and closer to the water table, the earth often contains more moisture and the problem is exacerbated.

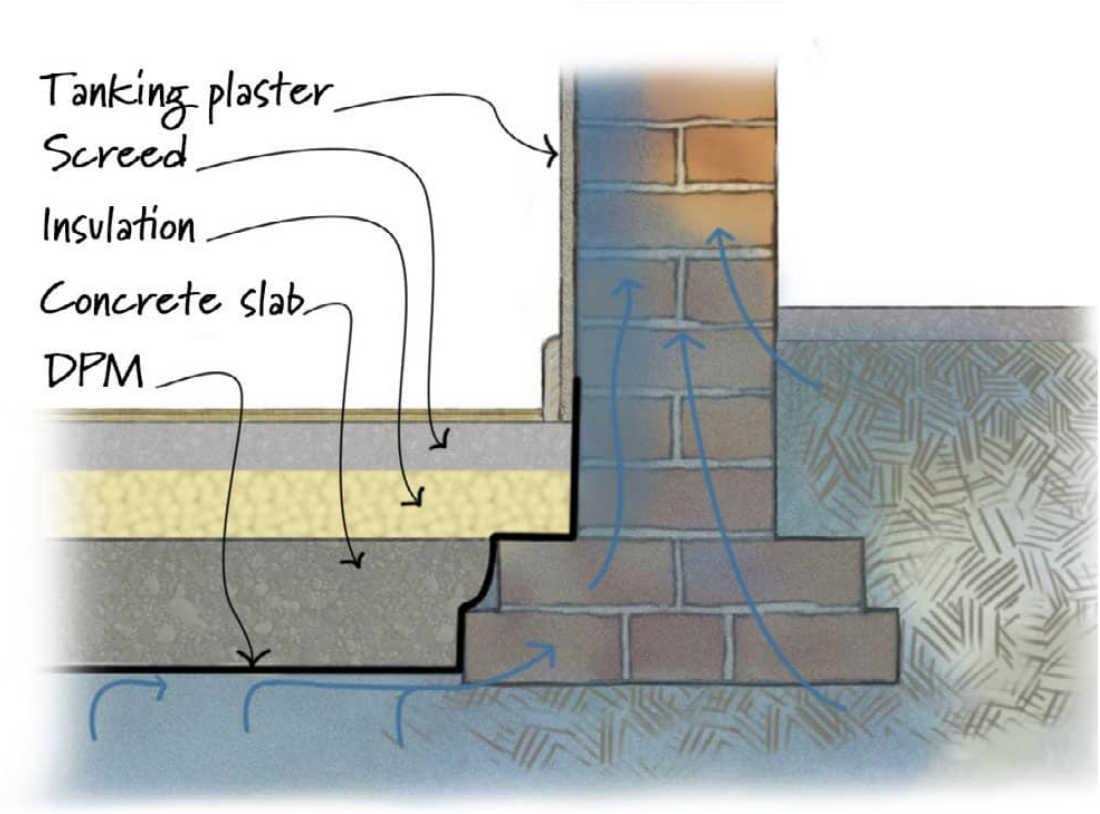
Until comparatively recently, concrete floor slabs and screeds were laid without any insulation incorporated. Unlike earth, which is an insulator, concrete is a reasonably good conductor so it feels cold to the touch. Where ceramic tiles or stone flags are laid directly on the concrete, the floor will feel particularly cold to walk on in bare feet during the winter months. Intermittent heat sources, which are only switched on for a couple of hours at a time, are rarely adequate to bring such floors up to a comfortable temperature; they may even cause condensation on the cold surface of the floor.

Dealing with a cold, solid, concrete floor remains one of the greatest challenges when upgrading for thermal efficiency. Occasionally, where the concrete was laid several decades ago, it might be of a limited thickness of 40–50 mm. It may be worth taking this up and starting from scratch. Doing this provides an opportunity to lay a breathable floor system, incorporating insulation and underfloor heating (UFH) within the new floor.

More generally, concrete slabs were laid between 100 and 150 mm in thickness, and some had steel reinforcement included, so removal is a major undertaking involving heavy machinery and vibration to the building. This level of invasive work may cause more damage than leaving the floor in place.

Assuming the concrete was laid on a DPM but is not pushing damp to the outside walls, it may be worth replacing the cold tiles or flags with a wooden floor, or even a carpet and thermal underlay. Both would act as

insulators and provide a degree of thermal comfort underfoot. If there is sufficient headroom, it may be possible to incorporate a thin insulating layer with electric UFH, or even a retrofit board designed for a wet UFH system.



Concrete slabs are often laid to resolve problems with damp floors but, as the DPM under the slab is not linked to a DPC in the wall, they tend to force ground moisture to the edge and create rising damp. Low-level impermeable tanking plasters are often used to mask the problem, but these push the moisture further up the wall, leaving the masonry damp and thermally inefficient.

Plaster floors

While concrete floor slabs are often unwelcome in old buildings, take care not to confuse them with plaster floors. In areas where gypsum was readily available, such as the Midlands, plaster floors were commonly laid from late medieval times up to the nineteenth century. They look surprisingly similar to concrete. Tragically they are often destroyed, as their historic value is not recognised.

LIMECRETE FLOORS

Developed in the late 1990s, limecrete floors have become established as a practical alternative to concrete floor slabs and thousands are in existence across the UK.

Limecrete floors are ideal for use where a solid, insulated ground floor is required but where the walls have no physical damp-proof course (DPC). In such cases, the installation of a concrete slab and DPM would risk pushing dampness to the walls, resulting in rising damp. Limecrete floors work particularly well when a stone flag, brick or ceramic tile floor finish is required, incorporating underfloor heating.

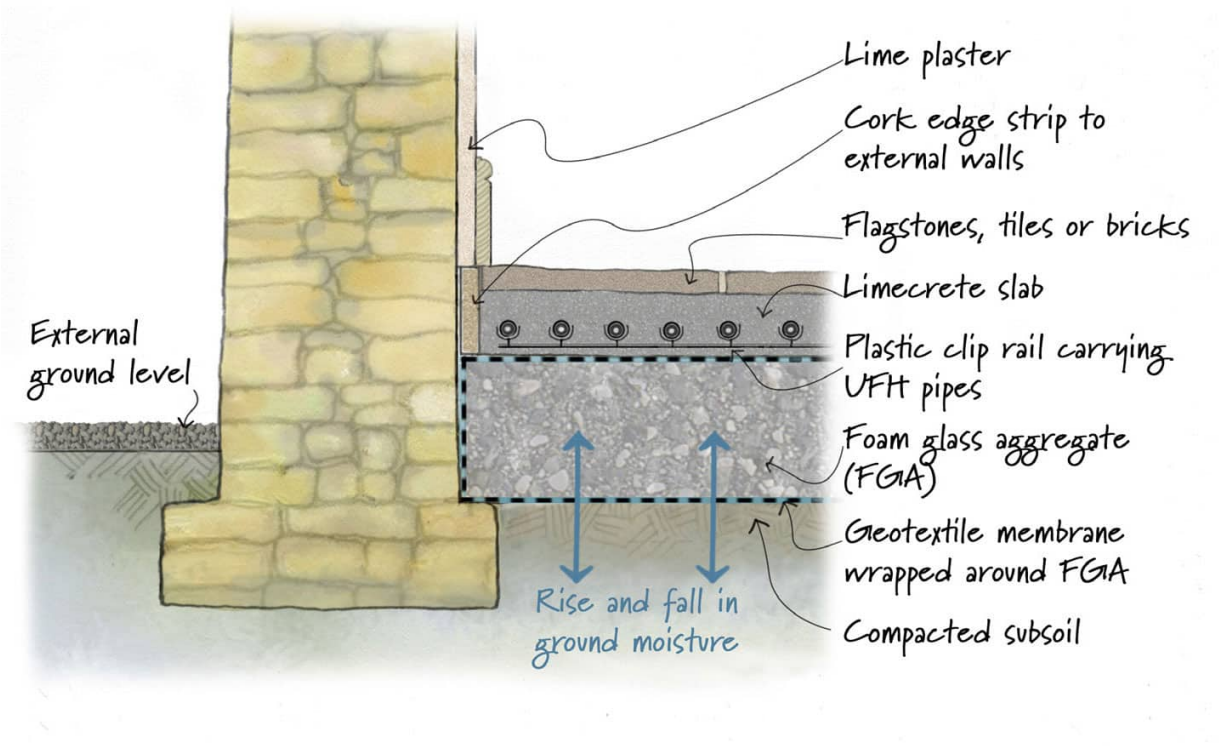
Limecrete is a material similar to concrete. Rather than being a mix of cement and aggregate, it consists of hydraulic lime and aggregate and can be used to make a structural floor slab that has a degree of vapour permeability. The principal difference between a limecrete floor and a standard concrete solution is that the former is laid on a sub-base of foam glass aggregate (FGA), which replaces the need for a DPM and all its associated problems.

Limecrete floors can be designed to meet the current building regulations for U-values. Certain suppliers have established their design as a Registered Detail, so it is recognised in all local authorities in England, Wales and Scotland. This helps to simplify the building control process.

If underfloor heating is incorporated, the mix for the slab should be as conductive as possible to allow heat to pass through it. If no underfloor heating is present, a lightweight slab can be cast, designed with a higher U-

value. This can be achieved by incorporating granules such as pumice within the mix. This would contribute to the overall insulation value of the floor and would form part of the U-value calculation.

Breaking up and removing a concrete floor is a major undertaking, but may be necessary in instances where it is causing damp in the walls.


Lime plaster
Cork edge strip to external walls
Flagstones, tiles or bricks
Limecrete slab
Plastic clip rail carrying UFH pipes
Foam glass aggregate (FGA)
Geotextile membrane wrapped around FGA
Compacted subsoil
External ground level
Rise and fall in ground moisture

A limecrete floor provides a breathable insulated alternative to a concrete slab and is more suited to an old building.

Designing out damp-proof membranes

In order to meet building regulations, solid ground-floor systems must provide a barrier to rising moisture. This is generally achieved with the use of a plastic DPM under a concrete slab. In a limecrete floor, the FGA is laid as a loose fill, and works as a substitute for a DPM. The large granules, typically 20–50 mm across, create air gaps that prevent any moisture rising up via capillary action. The granules themselves are closed cell, meaning that they cannot transport moisture from one cell to the next, and perform well in a damp environment.

If the water level rises within a limecrete floor, it is free to do so within the thickness of the foam glass, and to drain freely when the water recedes without causing damage. It is essential, as with all floor systems, that any ground water issues are resolved before the installation of the floor. This could involve the construction of French drains around the building or, in some cases, drainage may be necessary beneath the loose-fill insulation layer.

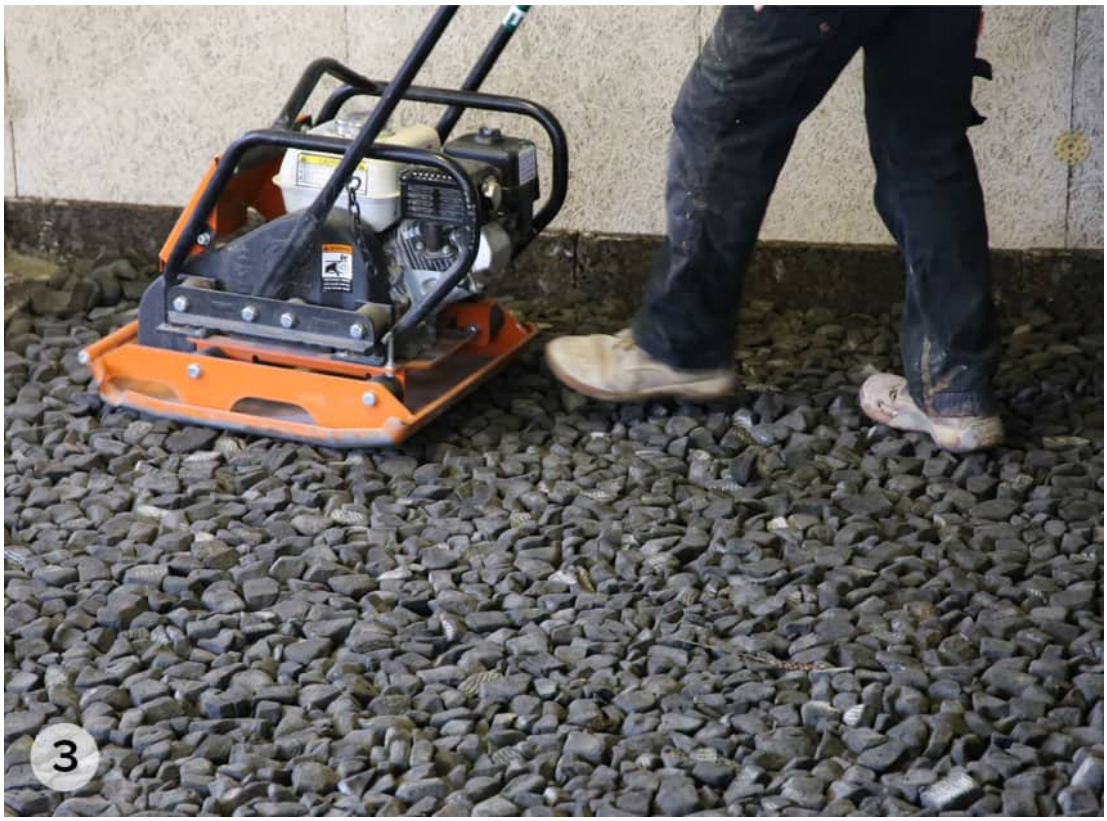
TOP TIP: WHAT LIES BENEATH?

When breaking through a modern concrete slab, investigate what is beneath. Old flags or tiles may still remain and be repairable.

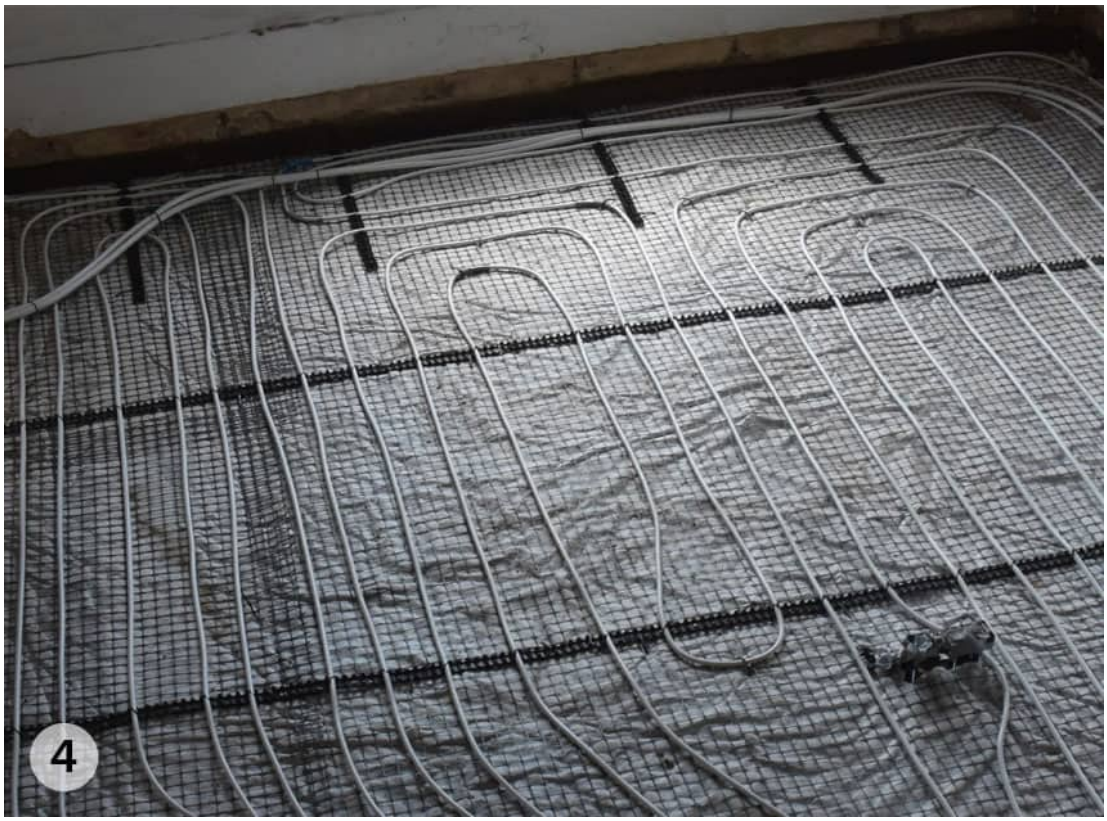
Laying a limecrete floor

Step 1: First, the earth within the building is excavated to a suitable depth and the ground levelled. Care must be taken not to undermine any footings. A geotextile membrane is laid on the earth to prevent silt from rising.

Step 2: The FGA layer is laid slightly thicker than required to allow for compaction. It is roughly raked level.



Step 3: The FGA is compacted using a vibrating ‘wacker’ plate. This causes the angular granules to settle and knit together, creating a sub-base that is stable to walk on and will not compress under load. A geotextile membrane is then laid over the top. This is principally to prevent the limecrete layer above from running down between the FGA and providing a path for water via capillary action. If a radon barrier is necessary, this is laid over the loose fill, but should be avoided if possible.



Step 4: If UFH is required, it is laid over the FGA and geotextile on purpose-made plastic clip rails. It is important to avoid plastic tray systems that cover the entire floor, as this will impede breathability. Ideally, a gap of 25 mm should be created between the underside of the UFH pipes and the top of the foam glass, to allow the cast slab to encase the pipe and form contact all the way around (See Underfloor heating, shown here). Insulating edge strips are also fitted at this stage around perimeter walls (See Edge insulation to solid floors, shown here).

Step 5: The limecrete slab is mixed next. It combines hydraulic lime and a well-graded aggregate. This is usually mixed on site by operating two mixers simultaneously to cope with demand. A standard cement mixer may suffice for this operation, although a paddle mixer might be necessary for larger areas. It should be carefully batched with water added to produce a porridge-like, semi-dry consistency.

Step 6: For very large floors, it may be economical to employ a specialist company that brings limecrete to site ready mixed.

Step 7: Once mixed, the limecrete is barrowed in, taking extreme care not to damage any underfloor heating pipes in the process. It is poured onto the geotextile in a similar fashion to casting a concrete slab and is levelled, using a straight edge.

Step 8: The limecrete is floated up, maintaining an accurate level.

TOP TIP: EDGE INSULATION TO SOLID FLOORS

Fitting edge insulation to the perimeter walls of solid floors prevents heat dissipating through low-level masonry; a compressible edge strip also allows expansion in certain floor finishes. Cork strip (top) is often used, but a closed-cell, compressible-foam insulation (bottom) may be appropriate, particularly if damp is a concern. Although non breathable, it covers a relatively small area of wall and moisture is free to evaporate around it.

Limecrete curing

There is a common misconception that lime takes forever to ‘go off’. A limecrete slab can usually bear weight within a day or two of laying, but ideally it should be left for a week before receiving foot traffic.

As with concrete, it is important to maintain temperatures above 5ºC (ideally between 10ºC and 18ºC) and to have good ventilation to control humidity. That said, in warm, dry conditions it may be necessary to dampen down the limecrete for several days to prevent rapid drying before carbonation has had a chance to take place. In general, it is wise to allow between three and four weeks before laying any floor finish or screed layer. This is to give time for the carbonation process, the mechanism by which it gains its strength, and also give time for the slab to dry. The total length of drying/curing time will depend on the thickness of the slab and the temperature and humidity levels on site. Underfloor heating can be turned on after two weeks, but the flow temperature must not exceed that of the slab and the temperature should only be raised by one degree a day so as not to shock the slab.

Limecrete floor finishes

The ideal floor finish to limecrete is stone flag, ceramic tile or brick. These should be laid in a compatible, breathable mortar or adhesive, and pointed or grouted with a suitable product to maintain breathability.

Wooden floors can be used if the floor has fully dried prior to laying boards. This can take two to three months. The boards should be laid on battens to maintain an air gap, although this makes UFH considerably less efficient. Take advice from your flooring supplier about the most appropriate type of wooden floor.

Carpets can be laid over a limecrete floor, but this usually requires the slab to be screeded to achieve a finish that is smooth and flat, which can add considerable expense. Such screeds are purpose-designed to be breathable, and can be ordered through a lime supplier. Avoid rubber-backed underlays or other non-breathable types; opt instead for a vapour-permeable underlay. Such underlays are more expensive and do not provide the same level of cushioning as modern equivalents, so always think this through when planning your floor. Coir and sisal mats are particularly suited to limecrete. Where carpet is the desired finish, consider an alternative flooring system as detailed below (See Solid, breathable dry-floor system, shown here).

Breathable floors and radon

When working within a radon area or where landfill gas is an issue, you may be required to take precautionary measures. Most retrofit solutions can be adapted to incorporate a radon sump and the necessary barrier membranes. If using foam glass aggregate as a sub-base, a physical radon barrier can be installed above it and vented to the outside using pipes passing through the wall, terminated with suitable grilles. Even with the barrier in place, the loose fill will still act as a moisture buffer, allowing ground water to rise and fall within it. For advice, speak to your materials supplier and consult a building control officer.

Limecrete: key issues

- A limecrete floor typically has a 250–500 mm build-up. If you are digging down to accommodate this thickness, be careful not to undermine the footings of the building. Dig a trial hole to establish the depth of the existing wall and, if in doubt, consult a structural engineer.
- Establish the level of the water table by digging a trial hole before excavating down to lay a floor. Although moisture can freely rise and fall within the loose-fill layer, the water table must not reach the limecrete slab as it has high capillarity and will absorb moisture.
- Make sure that the top of the loose-fill layer is above the external ground level, otherwise ground moisture may track across and create dampness within the limecrete layer.

Floors and U-values

Solid-ground floors bearing onto the earth lose heat at a much slower rate than other thermal elements such as walls and roofs. Earth is a reasonable insulator, and therefore resists heat flow through the floor construction. In addition, flags or tiles have high thermal mass, storing heat and re-releasing it as the temperature of the room cools.

As the floor is usually above external ground level, a thermal bridge exists around the edge of the room where heat flows through the external walls, cooling the floor at the perimeter. This means that solid-floor U-values cannot be calculated simply by looking at the detail and thickness of the construction materials. The heat loss takes into account the exposed perimeter, the length of floor abutting an external wall. Most companies offering floor-insulation products provide a free U-value calculator: specific details of the project are entered and the heat loss is calculated, along with the necessary thickness of a particular insulation product to meet building regulations.

U-values of suspended timber floors are easier to calculate, as the heat is lost to the ventilated cavity beneath.

U-values to floors take account of the exposed perimeter.

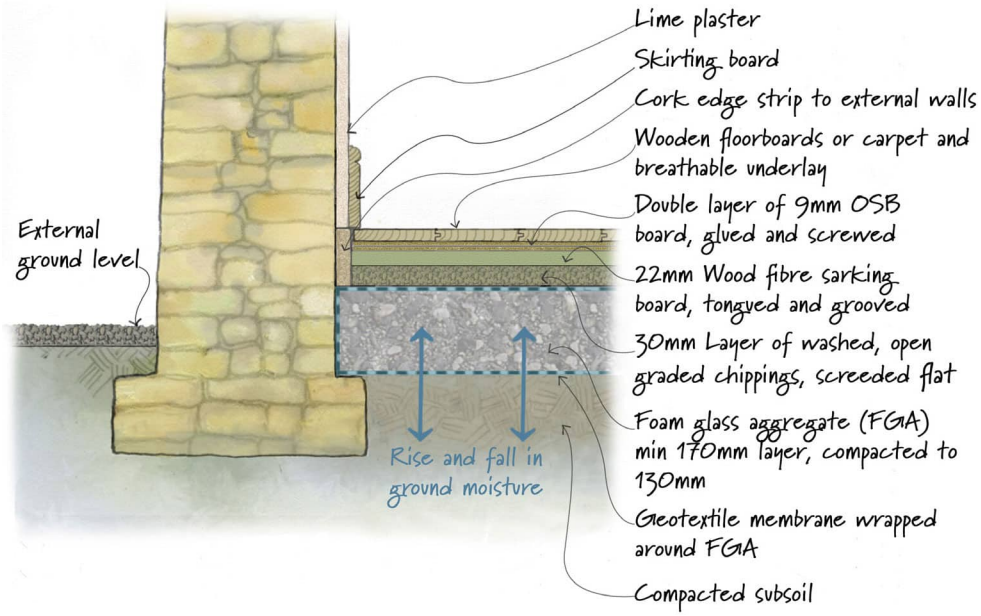
SOLID, BREATHABLE DRY-FLOOR SYSTEM

In recent years, new solid ground floor systems have been trialled that combine FGA and insulation boards. These do not need a DPM (See Designing out damp-proof membranes, shown here), which can aggravate

low-level damp, nor do they need a ventilated sub-floor void that is difficult to draughtproof. They also avoid the need for a cast slab that is expensive to lay and slow to cure.

Providing it is not of historic interest, the existing floor structure or slab is removed to prepare the area and get back to earth. If necessary, the ground is excavated further to the required depth, taking care not to undermine the base of the wall. A total minimum thickness of around 220 mm is needed if finishing with carpet – slightly more if a greater U-value is required or if timber boards raised on battens form the finished floor.

While it is well insulated, this floor system does not have much thermal mass, and therefore is not particularly effective where a wet underfloor heating system is required. The build-up can be adapted by using pre-formed screed replacement tiles, grooved to accommodate heating pipes. These are laid directly onto the wood fibreboard, and the OSB layer is omitted. The tiles spread the load and provide thermal mass, and are a good substrate for a stone or ceramic tile finish.


Lime plaster
Skirting board
Cork edge strip to external walls
Wooden floorboards or carpet and breathable underlay
Double layer of 9mm OSB board, glued and screwed
22mm Wood fibre sarking board, tongued and grooved
30mm Layer of washed, open graded chippings, screeded flat
Foam glass aggregate (FGA) min 170mm layer, compacted to 130mm
Geotextile membrane wrapped around FGA
Compacted subsoil
External ground level
Rise and fall in ground moisture

A solid, breathable dry-floor system is an alternative to limecrete in certain circumstances where speed of build is required.

Laying a solid, breathable dry-floor

Step 1: A geotextile membrane is laid directly on the levelled and compacted earth and lapped up the walls.

Step 2: FGA is laid above the geotextile, as with a limecrete floor.

Step 3: A minimum thickness of 170 mm FGA can be compacted to 130 mm in the final build-up, using a vibrating wacker plate. Check the required U-value for your project, increasing the thickness of the FGA layer as necessary. A second layer of geotextile is laid above the FGA following compaction. Ideally, an insulating edge strip should be fitted around the perimeter of the room.

Step 4: A 30 mm blinding layer of screeding sand is laid, without a binder of lime or cement, but it should have a small amount of water present to allow it to ball together. It is important to select a gritty, angular sand so that it can be screeded to form a perfectly flat layer. A competent landscape or groundworks contractor could potentially carry out the task.

Step 5: Once the layer has been raked to an approximate level, screeding poles are placed into the surface and set to the correct height using a laser level.

Step 6: The sand is drawn across the poles using a straight edge, to form a perfectly flat layer. The poles are removed in due course, taking care not to step on the sand.

Step 7: Wood fibre sarking board is laid above the sand blinding layer. Usually designed for over-rafter insulation, this board has a higher level of moisture resistance and compressive strength than usual, while still retaining good levels of vapour permeability; check the suitability of the board for this application with the supplier. Crucially, the wood fibreboard has a tongued-and-grooved edge, spreading the load as well as preventing any particles from passing through the joints.

Step 8: For further load spreading, two layers of oriented strand board (OSB) are laid above, glued and screwed together with staggered joints. These are also vapour permeable to some degree, so will evaporate any low-level moisture within the floor build-up. A 15 mm perimeter gap is required to accommodate expansion. Ideally, a carpet with breathable underlay or wooden boards should be laid directly on top.

SUSPENDED TIMBER FLOORS

When there was no cellar beneath, suspended timber floors were normally constructed by building a series of parallel ‘sleeper’ walls to carry joists at ground-floor level. These were built of ‘honeycomb’ bonded brick, which allowed air to circulate. Grilles, designed to draw ventilation through, were fitted externally at low level on opposite external walls to prevent the build-up of moist air that could rot the timber.

The drawback of ventilation under suspended floors was that the air flow caused a draught within the room, which had a dramatic effect on room temperature. The problem was exacerbated because, as the boards seasoned and shrank, the gaps between them increased. As sawmill technology developed, the tongue-and-groove floorboard appeared. The tongue bridged

the gap between the boards so, even when the boards shrank, the draught was greatly reduced.

Draughtproofing

A typical 4 x 4-m room has approximately 27 floorboards. If there is a 1 mm gap between each, the approximate total gap area is 0.1 m^2 – equivalent to leaving a small window permanently open. Consequently, making a suspended timber floor and the gap beneath the skirting board around the edge of the room as airtight as possible has a considerable impact on comfort and heat loss. Where a fitted carpet has been rejected in favour of exposed floorboards, considerable care is required to find a draughtproofing solution that is both functional and discreet.

For a simple, cheap and non-invasive solution, timber floors can be draughtproofed using a variety of proprietary draught-strip systems fitted within the gaps. They have a variable success rate but, where gaps are fairly narrow and regular, they are worth trying.

If the gap is large enough, use a screwdriver to push in a slightly larger foam strip; provided it stays in place and does not fall through, this will help to stop the draught.

More often, the gap is only 2–3 mm and may be filled with a bead of brown silicone mastic carefully applied with a mastic gun. Choose a product with a thin nozzle and push it as far as possible into the gap to fill the thickness of the space, then run your finger over the joint for a neat finish. A continuous bead should be just enough to stop the draught, but it may be broken if the timber shrinks or the boards deflect.

For a more traditional option, gaps between floorboards and skirtings can be filled with thin slivers of matching timber. Stained balsa wood is sometimes used, as it can be compressed into the gaps. Alternatively, stain lengths of string – or even sash cord for wider gaps – to match the colour of the boards and then, like caulking the deck of a ship, apply wood adhesive along the edges of the boards and push the string into place. Be sure to wipe off the glue as you work to prevent marking the timber.

Particular attention should be paid to the gap at the bottom of the skirting board around the edges of the room where the draughts will often be greatest. If fitting a carpet, make sure this is addressed before the fitters arrive as it will not be possible afterwards. If it is left, it will cause the edges of the carpet to attract dirt and moths. A bead of mastic or low-expansion spray foam should suffice or, alternatively, expanding compression tape (See Expanding compression tapes, shown here). If the skirtings are being removed, take the opportunity to tape the junction where the wall meets the floor before replacing the skirting board.

Ventilation grilles for suspended timber floors may have historic interest in their own right. This example also shows a slate DPC.

Suspended timber ground-floor construction.

There is currently much debate over the amount of ventilation required for a healthy sub-floor void beneath a suspended timber floor. Where the ground below is dry (and the water table is low) it might be that very little ventilation is required, and the main focus should be on minimising rot to joist ends that are bedded in the walls at low level. If you are considering reducing ventilation in a sub-floor void, always use a relative humidity sensor in any potentially vulnerable areas to monitor environmental conditions over time (See Monitoring, shown here). Where the water table is higher and the ground appears damp, ventilation becomes more crucial to avoid a build-up of high relative humidity in the void. In such instances, always check that the moisture is not the result of a leaky drain or waterpipe.

TOP TIP: PLUGGING HOLES

Redundant holes in floorboards left over from old pipe or cable penetrations must be addressed. This is easily done using a wine bottle cork cut to shape, smeared with wood adhesive and gently tapped into place so that it is flush with the top of the board.

Insulation of suspended floors

Even where draughts are minimised or eliminated, heat loss via conduction through a timber floor with a cold sub-floor void is considerable. Effective insulation requires access to the space between the joists. Where there is an unheated cellar below, or a crawl space of 900 mm or more, the job can usually be tackled from underneath and is relatively straightforward. If only a shallow void exists, the boards will need to be lifted; this should be done with care and is not always advisable.

Very often, old boards split in the process of lifting. If boards are tongued-and-grooved, it is extremely difficult to lift them without snapping off the tongue when levering them up. If they are re-laid without the tongue, their appearance will be ruined and the benefit of sub-floor insulation reduced by the increase in draughts. Early boards, which were not produced in a sawmill and therefore are of varying thickness, were painstakingly shaped on their reverse to fit over the joist and sit flush on the upper surface. Each

board therefore has a specific location, making it extremely difficult to relay.

For draughtproofing larger gaps, specially designed foam strips are available that can be compressed and forced into the gap, where they expand to fit tightly in place.

For smaller gaps (up to around 5 mm), a ‘V’-profile strip made from a flexible plastic can be pushed into the gaps and, in theory, will spring open and stay in position.

Old elm boards such as these are fragile and difficult to replace.

Floorboards were usually fixed with special ‘cut’ nails, which were designed to grip into the joist and reduce squeaks, making the boards particularly difficult to lever up. In high-quality floors, secret nailing was often used into the edges of the boards, making removal even more difficult.

Employ a skilled carpenter where floors are valuable. Non-powered hand tools should always be used as these provide maximum control, minimising damage. As floorboards are lifted, number them with chalk, record their position on a plan or use photographs. Store boards carefully to prevent them from warping or becoming damp.

Skirting boards may also have to be removed, resulting in further disruption. Where floorboards are lifted, always check thoroughly for damp and beetle infestation and deal with the causes as well as the symptoms.

If boards are likely to be taken up again in the future, or where they are above fragile ceilings, screw them down with slotted – rather than cross-headed – brass screws as opposed to nailing them down.

Before lifting old floorboards, always consider:

- Are the boards of particular character and age? Are the boards tongued-and-grooved? If so, lifting may best be avoided.
- Are the boards in good condition? If not, replacement may be inevitable, and insulation should be incorporated at the same time.
- Is the sub-floor structure in good condition? Sometimes earth and debris build up under a suspended floor structure, blocking ventilation and causing decay. Try lifting an individual floorboard or use a boroscope to check condition.
- If the floor bounces when it is walked on, it may require more extensive repair and strengthening to the structure.
- Beware of lifting the entire floor at once, as this can destabilise the joists and sleeper walls.

Insulation from above

If floorboards are easy to lift and are of no historic merit, or when the floor structure requires repair, insulation between the joists should be considered. Just 100 mm of insulation can reduce heat loss through the floor by 65 per cent, provided airtightness is also addressed.

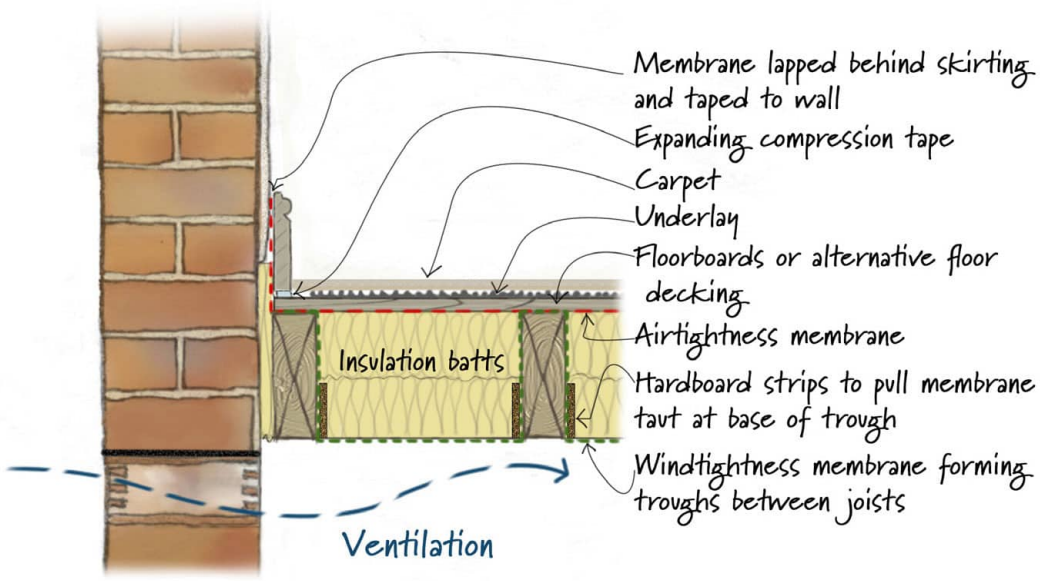
While boards are lifted, take the opportunity to remove any debris from the under-floor void, as this may hold moisture. Carry out any necessary repairs to the floor structure and strengthen joists if the floor is excessively bouncy. Check the condition of embedded joists ends and, if necessary, rehang them on joist hangers, isolating the end grain from the wall.

Effective insulation between joists in a suspended timber floor structure relies on three basic principles:

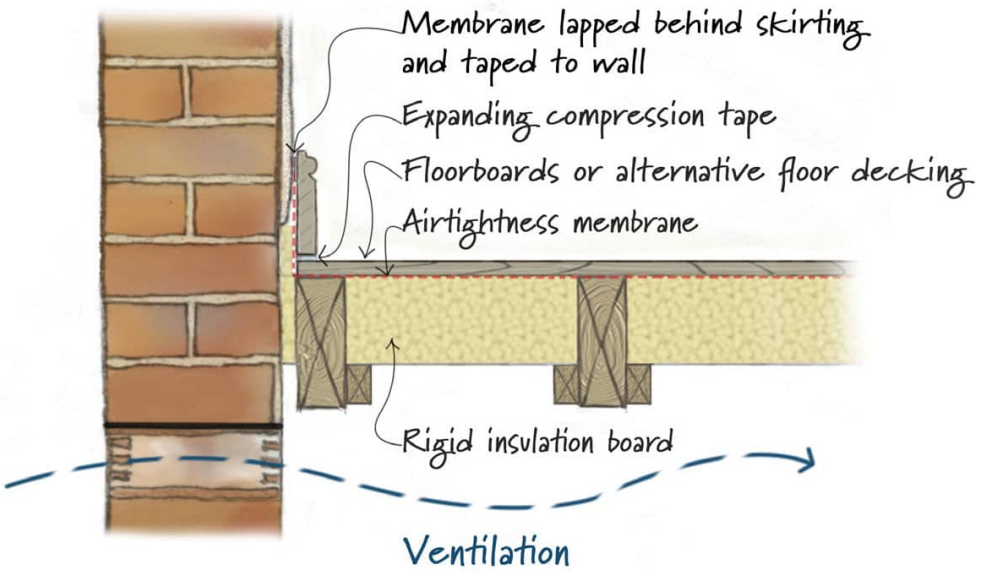
- The insulation needs to touch the sides of the joists and the underside of the boards, ideally with a slight compression fit. Any gaps will create a thermal bypass and dramatically reduce the efficacy of the insulation.
- While a compression fit is desirable, the insulation should not be excessively squashed. It can only operate at its designed U-value if it is puffed up to full thickness.

- When using an insulation quilt or batt, it is important to wrap the cold side with a breather membrane to prevent air movement; failure to do so will dramatically reduce its thermal value.

Insulation has been laid between these joists, but the lack of tight fit and failure to address airtightness will limit its effectiveness.



Batts can be used between joists, supported in a trough formed of windtightness membrane.



Where foam boards are used between joists, ensure that they are cut accurately for a snug fit.

Insulation batts between joists

A good way of insulating a suspended floor is to use stiff insulation batts – ideally of wood fibre – tightly fitted within the thickness of the floor. When installed from above, the simplest method is to form troughs between the joists using a breather membrane. The easiest way to do this is to start with

a long roll of membrane and tackle one trough at a time, fitting the insulation as you go, before moving on to the next. Forming the end of the trough is tricky and requires cutting slits into the membrane to form a corner.

This membrane is not intended to be fully airtight; it is simply to support the insulation and reduce air circulation within it. The top face of the insulation batt should be slightly higher than the top of the joist, to allow it to be compressed against the board, eliminating any gaps. If the batts are not stiff enough to support themselves they will sag in the middle, compromising the insulation. This can be remedied by stapling strips of hardboard or similar to the sides of the joists to pull the membrane taut. If using this technique, a loose-fill insulation such as cellulose, wood fibre or wood chip aggregate can also be employed as an alternative to insulation batts.

To create an airtight barrier, a second membrane – a vapour-control layer – is laid flat over the surface of the insulation and joists, lapped up the wall and fixed behind the skirting before the boards are relaid. Junctions to this membrane should be taped and any service penetrations must also be sealed. Always consider the implications of using this system under exposed floorboards in rooms where water is frequently spilt – for instance, bathrooms or kitchens. In such instances, the liquid may run through the gaps between the floorboards and sit on the membrane with nowhere to go, potentially rotting the timber from beneath.

Insulation batts suspended in membrane troughs may not be suitable in areas where rats or mice are prevalent, especially in situations where wall footings are shallow and there is a chance of burrowing underneath. In such situations, rodents may find their way into the sub-floor voids and nest. If in doubt, always leave a hatch in the floor, sealed and insulated, but providing access to monitor voids and, if necessary, deal with any infestation.

This floor has been insulated with troughs formed from windtightness membrane, filled with wood fibre insulation. The batts have been cut a little too wide, resulting in dips forming in the middle. These will create air gaps under the boards that will reduce the effectiveness of the insulation.

Rigid insulation boards between joists

Foil-faced foam or wood fibre insulation boards can be used between joists, but their rigid form prevents the compression fit achievable with batts. Boards are very difficult to fit tightly and gaps at their edges almost inevitably reduce their effectiveness, acting as a thermal bypass. Spray foam is often used as a gap filler, but it is rarely satisfactory, while gaps of less than 4 mm are too narrow to fill. There is also concern that the impermeable nature of spray foam, coating the sides of timber joists, will lead to moisture build-up and decay.

When fitting rigid insulation boards between joists, wooden battens must be screwed to the sides of the joists to stop the boards from falling through – but this is a fiddly job, as the battens must be set so that the board finishes exactly flush with the top of the joist (See right diagram, shown here). Failure to eliminate the air gap under the floorboards will result in a thermal bypass, especially when coupled with gaps around the side of the board.

Consequently, when using rigid board, it is prudent to lay an airtight membrane, lapped up and taped behind the skirting boards.

Insulation from below

If access is available from below, either from a cellar or an adequate crawl space under the building, the task of insulating a suspended floor is easier. Fix quilt or board material between the joists, pushing it up to fill any gap between the top of the insulation and the underside of the floorboards; a quilt should fill the full depth of the joist.

Another option when insulating from above is to use cellulose insulation, contained within troughs made of windtightness membrane.

Loose-fill insulation in sub-floor voids

A radical solution is to completely fill the sub-floor void to suspended floors with a closed-cell, loose insulation material, such as expanded polystyrene beads or FGA; it is essential that the loose fill used does not hold moisture. This method will, of course, prevent air flow in the void but, provided the earth below is dry, this may not be an issue. It offers an alternative solution to insulation batts where rodents are a concern, and is relatively quick to achieve.

Once insulated, fit an airtight layer to the underside of the joists. For example, tongued-and-grooved wood fibreboard will provide additional thermal and acoustic insulation. If the product selected is not fire-rated,

finish with two layers of plasterboard with staggered junctions where necessary.

FLOOR FINISHES AND UNDERLAYS

Lifting floor coverings to expose wooden boards can create cold and draughty interiors, and also reduce acoustic insulation between traditional floor structures. Thick wall-to-wall fitted carpets and thermal underlays are the easiest means of insulating suspended floors, particularly if the boards cannot be lifted. A floating floor of new timber or engineered boards laid on top of the original floor is another option.

Laying hardboard or OSB first, taped at the junctions, will improve airtightness and increase both thermal and acoustic performance. However, this is likely to require the base of doors to be trimmed, which may not be desirable or practical where historic joinery is present. If noise between floors is an issue, consider acoustic underlays.

In cases where high levels of thermal insulation at minimum thickness is a priority, an aerogel quilt bonded to a suitable board may be worth considering. A vapour-permeable floating floor composed of a 6 mm thick magnesium oxide board bonded to 5 mm increments of aerogel insulation is one solution. This system can accept all floor coverings but, if the floor needs to be breathable, these must be selected with care. To achieve airtightness, a membrane is required.

Where underfloor heating is installed, carpets and underlays will reduce the heat output and may not be compatible. Carpets are not always a solution for those suffering from asthma and allergies. A number of environmentally friendly floor finishes produced from recycled, natural materials offer alternatives.

Fitted coir and sisal carpets are attractive in old houses and provide insulation.

A floating timber floor, laid on thin insulating sheet, can improve thermal performance.

09 | PAINTS

Paints and other finishes are an easily overlooked part of the sustainability jigsaw. Their principal purpose is to enhance and protect. Less positively, their manufacture has the potential to be environmentally damaging and their use can impact both on human health and on old buildings that need to breathe.

Appropriately used, paints and other finishes help to maintain and extend the life of materials, saving wasteful replacement and, as a result, the use of natural resources and energy. Inappropriate use can prove disastrous, leading to dampness and decay.

When choosing a paint or finish, especially for exterior use, the priority should be for it to have a long-lasting finish – but this must be balanced by the need for it to work in sympathy with the building and its occupants. The least ecological product of all is one that fails to work, or results in problems that lead to the loss of a building's fabric, or makes the people using it or living with it unwell.

There is a vast range of coatings available and evaluating them is a hugely complicated and sometimes emotive subject. Even specialist chemists find it hard to agree on what constitutes an environmentally friendly paint, and product information is often misleading. It is generally extremely difficult to create a coating that is going to provide good durability, coverage and ease of application without environmental consequences. What is certain is that some so-called eco, green, natural or organic paint products are far more virtuous than others.

As well as providing essential protection, paints add individuality to houses.

Natural pigments provide a palette of rich colours and, when mixed with limewash, allow the wall to breathe.

Colour can dramatically alter the appearance of a building, but choosing the right type of paint is essential. Dark colours on south elevations will tend to degrade faster than light colours.

The masonry paint on this rubble-stone cottage was trapping moisture (above). It was removed using ‘scutch’ hammers, repointed in non-hydraulic lime and limewashed, allowing it to breathe (below).

THE PURPOSE OF PAINTS

Paint technology has come a long way since the days of simple limewashes and distempers. Those paints were made from materials that were readily available, and were often mixed up on site and applied as part of an ongoing maintenance cycle. Limewash was used annually on buildings associated with animals, to exploit its alkalinity as a means of killing germs. Patented paint formulations started to appear from the nineteenth century and ‘washable or sanitary distemper’ was developed as a more durable finish to soft distemper in response to growing hygiene standards.

Today, paint and other finishes protect surfaces from the damaging effects of moisture, ultra-violet (UV) light, atmospheric pollution and general wear and tear, and make cleaning easier. Paints are developed with permanence, durability and flexibility in mind, as well as ease of use, yet there is often a trade-off between durability and breathability.

Paint formulations for wood are generally different from those developed for plaster and masonry, and most paints are designed for either interior or exterior use. Other specialist paints are available for almost any substrate. Yet, with all these scientific advances, when it comes to old buildings there is a general move back to simple paints that allow our homes to breathe.

The problem with ‘modern’ paints

There is a common misconception that, to keep moisture out of an old wall, a waterproof paint has to be used. Yet old buildings move; they expand and contract, and are subject to seasonal movement due to their shallow foundations, causing hairline cracks in the structure, render and paint finishes. The waterproof nature of modern paints causes rain to run off wall surfaces without being absorbed but, when water finds a crack, it is concentrated and sucked in through capillary action. Once it has penetrated the waterproof paint layer, it is absorbed and dispersed and unable to escape. In addition, any residual moisture in the core or water vapour passing through the breathing wall is also trapped by waterproof paints. Depending on the situation, transparent waterproofing treatments to brickwork and stonework perform in much the same way, potentially trapping dampness within, rather than keeping it out, so are therefore best avoided.

Breathable versus waterproof

It may seem counter-intuitive, but the best way of keeping a wall dry is to coat it in a breathable paint – although it must be remembered that applying a breathable paint on top of a non-breathable one will not provide breathability.

In theory, breathable paints have a degree of vapour permeability so they allow moisture vapour to pass through them, preventing it from building up in the core of the wall. This is advantageous in many situations, but particularly when used on solid-walled, traditional constructions where the unimpeded passage of vapour is crucial to the longevity of the building.

Some breathable paints are capillary open and have high capillarity. This means that they are able to absorb water as a liquid. Traditional paints, such as limewash, casein and distemper, come into this category and are easily identified as they darken in colour when they get wet. This is a particularly beautiful quality that modern alternatives cannot replicate. By absorbing water over a large area, they also prevent rain from washing down the face of a wall and becoming concentrated at the base or in cracks.

While capillary-open paints are ideal for evaporating large quantities of water, they are not always suited to very exposed situations where rain may penetrate deep into the wall if unimpeded. For this reason, most modern breathable paint formulations, such as silicate-based paints, contain hydrophobic additives to stop liquid water (rain) from passing through them. Such paints are vapour open while remaining capillary closed. The tradition of adding tallow or linseed oil to limewash developed due to the desire to make the coating shed water in a similar fashion but, unlike hydrophobic additives, tallow and linseed oil also block the passage of water vapour and can trap moisture. For this reason they are best avoided, except on surfaces where rapid water run-off is desirable, such as painted external cills or coping stones.

If paint darkens as it gets wet, it is not only highly breathable but capillary open, and able to absorb liquid water.

What is particularly concerning is the vast number of paints that claim to be breathable but are neither capillary open, nor vapour permeable. Breathability is a relative concept and is often not quantified. Some manufacturers are producing paints that are marginally less waterproof than their forerunners and marketing them as breathable when, in practice, they are not. If a supplier cannot provide a value for breathability, you may wish to consider an alternative product.

Defining breathability

Paints with the highest level of breathability have an Sd value of less than 0.14 (See Measurements of breathability, shown here). With any type of paint, its breathability will decrease when pigments and other additives are mixed in.

WATER-VAPOUR PERMEABILITY	CLASS	SD VALUE
High	1	Less than 0.14 m
Medium	2	Between 0.14 and 1.4 m
Low	3	Greater than 1.4 m

Paint and wood

Paint systems for joinery, such as windows and doors, are more complex. Wood swells and contracts according to its moisture content, so any paint finish must be flexible enough to accommodate this movement without cracking. Cracks in timber, particularly on flat surfaces like window cills, will allow water to penetrate and rot the timber. Blistering is another common paint failure, caused by moisture in the timber trying to escape but being prevented by a waterproof paint. Vapour-permeable paints have been developed for joinery so that any residual moisture in the timber can escape, yet they may do more harm than good in situations where there are large fluctuations in relative humidity. As well as letting vapour out, they could potentially allow water vapour in, causing timber to swell and windows and doors to stick. In such instances, it may be preferable to use a waterproof finish and ensure that the wood is dry before application. Ideally, external joinery should only be redecorated following a clear couple of weeks of dry, warm weather that has reduced the moisture content of the timber. In reality, this may be impossible.

The myth of microporous

Many paints designed for joinery are branded as ‘microporous’ although this is, strictly speaking, a misnomer: a material can contain pores, but unless these are linked, they will not allow the passage of water vapour and will have no bearing on vapour permeability (See Porosity and vapour permeability, shown here). In reality, a microporous paint may have little or no capacity to breathe. The term was invented in the 1980s and used for marketing purposes, but has never been scientifically defined.

Always choose an appropriate paint for a particular application.

Matt or gloss?

There is a compromise to be made when choosing a paint for an old building. Matt finishes are generally more breathable, but they are not as durable as paints with some degree of sheen or gloss. Anyone with young children will appreciate the vulnerability of paint finishes when faced with sticky fingers and boisterous play. Also, surfaces that receive extra traffic and are regularly touched, such as stairwells and hallways or around light switches, will deteriorate more quickly if decorated with a completely matt paint such as soft distemper. Conversely, paints with a gloss finish are usually highly impermeable but generally the most durable. Therefore gloss paint may be very practical on a skirting board, which is subjected to knocks from the vacuum cleaner, but potentially disastrous on a breathing wall. Oil-based gloss paints tend to be more durable than water-based (acrylic) paints.

Paints are available in matt or gloss, but have different levels of durability.

UNDERSTANDING PAINTS

Modern paints are more complex than traditional formulations, but all are generally composed of binder, solvent and pigment. The binder, or vehicle, is the most crucial part and is the ‘film former’, creating a thin layer that

adheres to the substrate. Typical binders in traditional paints are glue size in soft distemper and linseed oil in traditional oil paints. Binders in modern paints include alkyds and acrylics.

The solvent dissolves the binder and thins it to control the viscosity of the paint. Water is the solvent in a water-based paint such as a modern acrylic. Oil-based paints contain organic solvents such as alcohol or white spirit. In all paint systems, the drying process includes the evaporation of the solvent, hence oil-based paints have a strong smell for several days after they have been applied. Ideally, rooms should be vacated while this ‘off-gassing’ is taking place. The same solvent is usually used to clean brushes after use.

Pigments give colour to paint. Ground to a fine powder, they are distinguished from dyes as they are insoluble. White is the most important pigment and is present in most paints, controlling the intensity of the colour and providing opacity; it is needed even with dark colours to avoid translucence. Traditionally, white lead was used. Today, titanium dioxide (TiO_2) is the most widely adopted white pigment in paints because of its high opacity and brilliant whiteness, minimising the number of coats required to achieve coverage.

Often fillers are used to bulk out and thicken paint and improve its texture. These are usually inert materials such as talc. Complex, modern paints contain a variety of other additives; combining all these ingredients in appropriate proportions creates the required colour, coverage or opacity, thickness, flow, uniformity and drying characteristics.

Horizontal surfaces such as cills rely on durable paint finishes to stop water from penetrating. Choosing the correct paint for the substrate is vital: timber requires a different type of paint to stone.

MINIMISING THE IMPACT OF DECORATING

Although many people regard decorating as a simple matter of picking a colour and slapping it on the wall, the choice of paint needs careful consideration. This is particularly true with an old house, if it is to be sustainable for the building and the environment.

Despite a move towards non-petrochemical-based products, all paint has an environmental impact. For some, it is much greater than others. Unravelling the true nature of a coating's eco credentials can be far from straightforward. Although many of the factors that need to be assessed to determine the suitability of a product, such as the method of production, distribution and use, are little different from other materials in sustainability terms, the ingredients and performance characteristics of paint are diverse and frequently complex.

Functionality and performance are essential. Paints and finishes that need many coats or frequent reapplication inevitably mean that more product is

used. This may require the cleaning off or removal of previous coats, possibly resulting in the use of hot air guns or chemical strippers.

To save on waste, test a small quantity of paint before committing to buying a large tin.

These factors must be balanced with the health of the building fabric, the health of the environment and the health of the people applying the coating and occupying the building. In many cases, the products used with old buildings will need to be breathable. From the environmental perspective, longevity, renewability, recyclability and biodegradability must all be considered.

The single most environmentally damaging component of paint, beside the various solvents used, is titanium dioxide. Although it is an abundant natural element, it is not easily accessible and needs a great deal of purification, so its production has a significant impact when it comes to the use of resources, energy, habitat loss and waste. But there are few effective alternatives. With pigments, it is generally worth noting that not all natural colours are as eco as they may appear. For example, the production of natural red oxide involves the red ochre pigment being mined, washed, burnt and crushed.

The texture of these wattle-and-daub panels is so appealing that the homeowner opted to leave them undecorated.

Colour choice

A huge range of pigments is now available, making it possible to mix virtually any colour. Originally choice was extremely limited. The earliest colours were provided by earth pigments, such as ochres, umbers and siennas, producing a range of yellows, browns and reds. Still available today, these are natural inorganic pigments and were simply dug from the earth and then ground to a powder; now they are often mined and processed. Earth pigments are relatively cheap and colour-fast, and are ideal for tinting many types of paints. Most traditional limewashes are based on this colour palette.

The search for a wider range of colours during the Industrial Revolution resulted in a wide variety of synthetic inorganic pigments such as Prussian blue, which are made by mixing and processing a variety of naturally occurring ingredients.

Confusingly, synthetic organic pigments are generally derived from non-sustainable petrochemicals. These colours are often brighter and stronger than their inorganic equivalents and can have good fading resistance, but they lack the subtleties required for a more period palette.

Natural clays dug from the earth provided the earliest colours.

Solvents are equally complicated. Organic solvents are dangerous both as producers of volatile organic compounds (VOCs) and because they can be serious irritants to skin and are generally considered to be more environmentally damaging than those that are water based. Even so, certain

natural solvents such as citrus oil and turpentine are increasingly restricted because of concerns over health. For the same reason, most manufacturers are reviewing the use of preservatives and biocides as well as surfactants and phthalates, which are thought to be hormone disrupters.

Volatile organic compounds (VOCs) in paints

Volatile organic compounds – chemical compounds that vaporise – are found in many building materials. Paints, finishes, thinners and brush-cleaning products tend to be among the most high-profile contributors to problems associated with VOCs. They can affect decorators using the products and those who occupy a building because the ‘off-gassing’ continues even after a coating has been applied.

Organic solvents are the main, though not the exclusive, source of VOCs in paints. A smell indicates that VOCs are present, and these can come from a variety of sources. For example, rather than a synthetic solvent such as white spirit, some paints contain an orange oil-based solvent with a typical citrus odour.

Very few proprietary paints are totally free of VOCs and low-odour paints do not necessarily have low levels of VOCs.

VOC levels are being reduced. By law, manufacturers of all types of paint have been forced to change their formulations to reduce the VOC content of their products. Regulations were originally introduced in 2007 to minimise, monitor and control the harmful effects of VOC content. Further reductions in VOC limits have been introduced since and paints must be compliant in formulation and labelling.

Why paints fail

The principal reasons for failure in paint relate to the expansion and contraction of the material to which they have been applied, the trapping of moisture, the deterioration of the underlying material, UV degradation due to solar radiation or poor surface preparation. As a result, paints may crack, flake, peel, blister or lose their colour. Always choose a paint and compatible primer suitable for the application. Ensure surfaces are dry and dust free and read the manufacturer's instructions carefully. For true sustainability when redecorating, aim to maximise the life of the paint layer as well as protect the surface beneath.

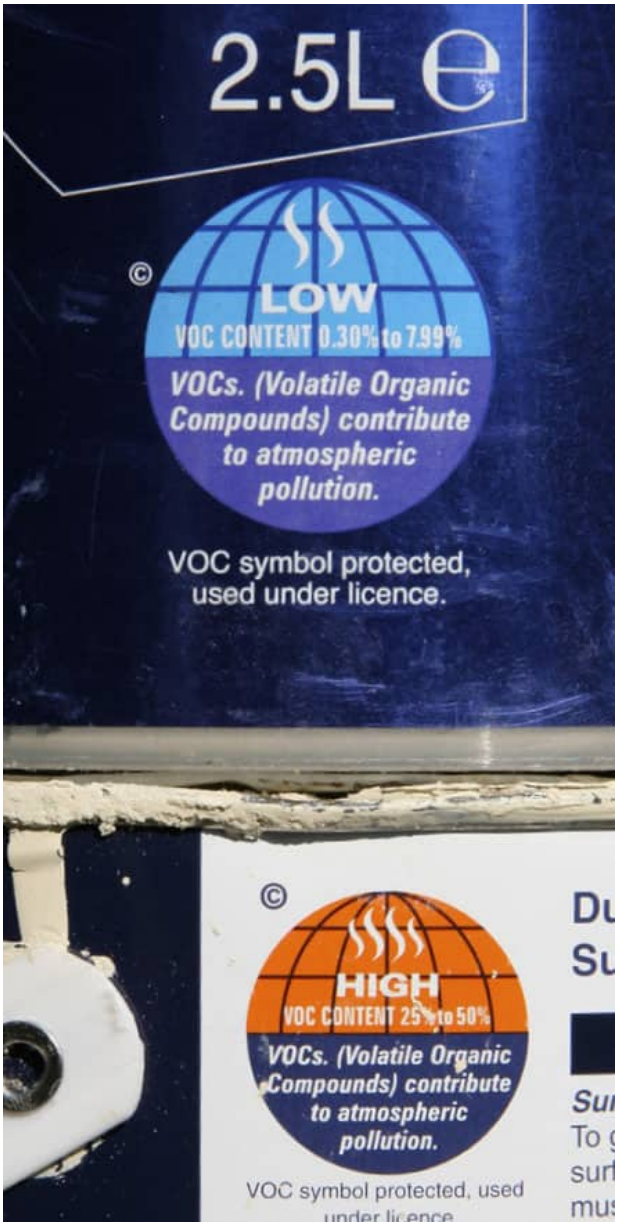
Masonry paint applied to a damp wall can become detached.

Paint finishes to joinery rely on careful preparation and are vulnerable to expansion and contraction of the substrate.

SURFACE PREPARATION

Paints and finishes are only as good as the substrate to which they are applied, so manufacturers often recommend removing all previous paint layers. At the very least, peeling and flaking paint must be removed, but many sound traditional finishes are best left undisturbed. Any attempt to strip them will involve releasing toxins into the environment, so always think whether such work is really necessary.

If applying a breathable paint (for instance, a limewash), it is necessary to remove any modern, impermeable paints first. There are two reasons for this: first, limewash will not stick to modern paint and, second, the wall will not benefit from the breathable quality of the limewash if the modern paint remains.


2.5L e
LOW
VOC CONTENT 0.30% to 7.99%
VOCs. (Volatile Organic Compounds) contribute to atmospheric pollution.
VOC symbol protected, used under licence.
HIGH
VOC CONTENT 25% to 50%
VOCs. (Volatile Organic Compounds) contribute to atmospheric pollution.
VOC symbol protected, used
Always try to use paints with a low VOC content.

Defective plaster and rotten timber should be made good and all damp problems resolved. If possible use natural, breathable fillers and always make sure that primers are compatible with subsequent coats.

This early wall painting was exposed while making the wall ready for redecorating.

Time spent preparing the surface will increase the longevity of the paint finish.

Check the eco credentials of your paint – not all are what they say on the tin.

Be aware that, in removing paint, you may destroy historic decoration so, wherever practical, leave sound earlier layers and simply paint over the top. When removing old paint or wallpapers, keep fragments and record their position as part of the history of your home. If you have a house predating the eighteenth century, it may contain wall paintings under later coatings, while Georgian and Victorian buildings might have stencilled or decorative schemes. Should you spot fragments of different colours and suspect you have something of historic interest, contact a paint conservator before going any further.

PAINT TYPES

Traditional finishes such as limewash, casein paints, distempers and linseed oil paints are all, in effect, eco paints. Today, they have been joined by paints branded as ‘eco’ from a wide range of manufacturers, but it is important to understand the true nature of these products. Some mainstream paints that give the appearance of being green have simply had their formulas changed to meet stricter regulations. Paints that are truly environmentally friendly offer a real alternative to products made from petrochemical derivatives.

Paint removal

If paint needs to be stripped, consider the product you use. Some chemical paint removers give off fumes and are irritating to exposed skin. They can also be damaging if they make their way into water courses, so responsible disposal is crucial. A number of solvent-free water-based paint and varnish removers are available that do not cause skin burns, are odour free and biodegrade. Unfortunately, the more environmentally friendly formulations often tend not to work as well.

If you are stripping impermeable paint finishes from old lime plaster, try using a wallpaper steamer to soften and lift the paint before gently scraping it off with a wide blade. ‘Bone glue’ is also used to remove modern impermeable paints from plaster substrates. The glue is applied hot and left overnight to contract. As it shrinks, it pulls away the modern paint from the surface. Whatever system you use, always carry out a trial first and ensure chemicals are properly neutralised.

A chemical is applied to react with and soften the old paint.

After a specific ‘dwell time’, during which the chemical reacts with the paint, a scraper is used to remove the paint. The process often has to be repeated more than once.

True eco paints are far more likely to meet the needs of older buildings. They have high vapour permeability compared to so-called breathable or microporous paints. In addition, they are made using predominantly renewable natural materials and are designed to be as non toxic as possible. Some brands supply their paints in recyclable containers and packaging. Most have little or no smell.

These paints vary from brand to brand and are generally relatively easy to use, although more care is needed than with conventional products. This is especially true when it comes to application, as some show brush and roller

marks more than mainstream products. There are also differences with drying times: eco paints generally take longer to dry than conventional paints, so you need to think more carefully about scheduling your project.

Casein or milk paint Useful for: internal wall and wood surfaces

Consisting principally of casein (a milk protein) and lime, casein paints provide a soft, matt finish and can be applied to most internal surfaces. They have a beautiful texture but they lack durability, so are impractical for some areas. For example, they are not recommended for use on windows or doors, as they cannot be wiped clean and do not resist knocks. They often come in powder form and have to be mixed with water and pigments. Although they are highly breathable, they are not suitable for damp walls or humid rooms such as kitchens or bathrooms, as the surface will be susceptible to mould growth. Casein paints do not generally contain titanium dioxide and are free of VOCs, acrylics, oils and solvents.

Casein paints give a beautiful texture and are extremely eco friendly, but lack durability.

Safety

When preparing surfaces for painting always take sensible precautions:

- Wear a good-quality mask when sanding or stripping surfaces and when mixing paints supplied in powder form. Use wet-and-dry paper rather than sandpaper.
- Protect your eyes by wearing goggles when sanding or stripping surfaces, including stripping wallpaper, especially where it has been painted.
- Wash solvents and paints off skin promptly, following the manufacturer's recommendations.
- Use ear protectors when mechanically sanding.
- Open windows when burning off paint with hot-air guns and when using paints or solvents that give off fumes.
- Understand the dangers of lead paint and take appropriate precautions.
- Be aware of the risk of fire when using hot-air guns, especially near areas where dust may be lodged, such as in sash boxes. Stop any 'hot works', such as the use of hot-air guns, at least one hour before leaving the site and make sure that the area is thoroughly checked prior to locking up.
- Never use blow lamps for paint removal.
- Take great care when working off ladders and platforms and do not overreach.
- Be particularly mindful of dust and fumes if children are living in the house while work is undertaken.

Always wear appropriate safety equipment.

Clay paint
Useful for: internal wall surfaces

Offering a greener alternative to emulsions, clay paints provide a soft, matt finish, are suitable for most interior substrates and come ready mixed. They have excellent coverage, often requiring only one coat, provide good durability and are available free of odours, VOCs, acrylics and oils; some are free of titanium dioxide. Clay paints are ideal for both new and old lime plaster, but can also be applied over modern paints or gypsum plasters. Certain clay paints are self-coloured by their natural mineral content.

Clay paints have a similar texture to distemper, but are much easier to use.

Clay paints are vapour permeable and capillary open, allowing surfaces to breathe and absorb moisture. This helps to regulate the internal humidity of the building and makes them ideal where condensation is a problem, but they should not be used on damp walls.

Contract emulsion
Useful for: internal walls and ceilings

The term ‘emulsion’ refers to a suspension of tiny droplets of one liquid in a second liquid that ordinarily do not mix together; in this case, tiny drops of vinyl (a petrochemical material) in water. This produces a gel-like consistency in which a pigment can be suspended. Emulsions took over from washable distempers in the mid-twentieth century. Standard, modern emulsions have either vinyl or acrylic resin added to make them more hardwearing and wipeable, but this also makes them considerably less vapour permeable.

Trade paint suppliers stock ‘contract emulsions’ that contain no vinyl. These are designed to be applied as a base coat to new gypsum plaster that has not fully dried out, speeding up the construction process. While contract emulsions are not as durable as their vinyl counterparts, they serve a useful purpose in old buildings as they allow some degree of water vapour to pass through, making them far more suitable for solid walls. Their lack of vinyl gives them a completely matt finish that is often more in keeping with a period aesthetic. Contract emulsions do contain biocides, surfactants and coalescing agents, as do other standard emulsions.

Lead paint crazes over time, leaving a distinctive and beautiful patina.

Lead paint
Useful for: external timber

Although it is potentially toxic, lead paint is breathable, flexible, offers unrivalled durability on timber and has an attractive texture and mellow appearance. Compared with modern oil paints, it emits fewer VOCs. It is composed of lead pigment – usually lead carbonate (‘white lead’) – bound in oil and can be tinted with colour. In recent years lead paint has been banned, except for use on certain listed buildings of high grade. Due to the restrictions imposed on manufacturers, it is expensive and not widely available. Linseed oil paint is a good alternative to lead paint in terms of its appearance and durability.

Limewash
Useful for: breathable external wall surfaces

The ultimate eco paint and the most breathable coating available, limewash is basically lime putty (calcium hydroxide) and water. It can also be made directly by slaking quicklime and is then used hot. This method has health and safety implications, and great care should be taken, but some specialists believe it to be a better way of bonding the limewash to the substrate, particularly in exposed situations.

Limewash should be applied to a dampened substrate in thin coats; these are translucent when wet but become opaque as they carbonate.

Limewash reabsorbs carbon dioxide and carbonates as it dries, providing a breathable, solvent-free, decorative matt finish. It is ideal when applied to lime or clay plasters and renders, soft brick and some stone. It can also be applied to weathered oak on timber-framed houses. It requires a degree of suction (capillarity) in the substrate in order to stick. To test the suitability of a background, try splashing some water on and observe how quickly it is absorbed. For surfaces where the water runs off, such as cement renders, hard stones such as granite and dense bricks, limewash is less successful, as it is unable to key with the substrate. It is not suitable for plasterboard or gypsum plasters and will not adhere to modern impermeable paints such as emulsions and masonry paint.

Limewash is usually applied in up to five thin layers. Due to its watery nature, messy application and the number of coats required, it may not be the first choice for internal application, particularly on ceilings, although some people prefer the aesthetic of limewash and are prepared to put up with its peculiarities. It can be very useful on internal walls that are drying out, as its breathability remains unrivalled and most other paints would blister or flake in that situation. When used externally, it typically needs renewing every four to five years but this is dependent on the suction of the substrate and the exposure of the building. For a rough rule of thumb, each coat of limewash will give one year’s protection.

Dealing with old lead paint

Always consider whether lead paint is present before doing anything that may disturb it. Lead was employed in many paints applied prior to 1970 and its existence can be confirmed by specialist analysis or by using a DIY test kit. When sanding down old joinery, the presence of lead should be assumed – so always obtain comprehensive information about how to go about the process and the precautions that must be taken. Remember:

- The main health risk occurs when lead compounds are ingested or inhaled due to unsound or disturbed paint.
- Children and pregnant women are particularly vulnerable to lead poisoning.
- Dust is the greatest hazard, especially from the inappropriate sanding of old lead paint.
- It may be safer to renew or overcoat lead paint than to attempt its removal.
- Because it tends to erode rather than peel, surface preparation may require little more than washing with sugar soap. Only loose paint needs to be scraped off.
- Where necessary, a light rubbing-down using wet (not dry) abrasive paper or chemical strippers may be the solution. Never use hot-air guns due to the fumes that are released.
- The presence of lead paint does not justify stripping historic joinery.

Rather than flaking like most modern paints, lead paint often remains sound and can be overcoated rather than stripped back to bare wood.

Linseed oil paint
Useful for: external joinery

Linseed oil paint is the original form of oil paint. Applied correctly in a sheltered location, it can last more than ten years before it needs to be reapplied. The paints do not contain any solvents or preservatives and are breathable. The linseed is extracted from the seeds of the flax plant, a renewable and sustainable resource. Natural pigments, generally containing no added solvents, are used to provide colour, although titanium dioxide is employed. On external surfaces, zinc oxide is added to the first coat as a barrier against possible mould growth. This can either be added at the point of use or purchased ready mixed.

The process of applying linseed oil paint is relatively simple, but always follow the manufacturer’s instructions. Ideally the paint should be applied to bare wood, as it penetrates the surface of the wood, helping to keep moisture out but, where sound historic paint exists, it can be applied over the top. As it dries, linseed oil paint forms a flexible film, so it is more resilient to cracking than many other coatings. Over time the surface of the paint oxidises, becoming chalky and matt, but the wood remains protected. The downside of linseed oil paint is that it takes quite a long time to dry and must be applied in very thin coats. If it is applied too thickly, the paint forms a skin and stays wet underneath.

Mixing limewash

Step 1: Part-fill a plastic dustbin with clean water, and mix approximately three parts water to one part lime putty.

Step 2: Use a plasterer’s whisk fitted to an electric drill to mix the limewash.

Step 3: Test the consistency by dipping in a metal blade. The limewash should be similar to full-fat milk, forming a line along the blade but remaining translucent.

Step 4: For internal use, sieve the limewash through a pair of tights to remove any grit and lumps.

Step 5: If tinting limewash, mix a compatible pigment with hot water by shaking the two together vigorously in a jam jar.

Step 6: Add the pigment to the prepared limewash and mix thoroughly. Test the strength of the colour.

As the limewash absorbs CO2 it converts to calcium carbonate, becoming more opaque and lightening in colour. Limewash is ideal for this timber-framed house, where it is applied over the lime-rendered panels and frame to maximise breathability.

Applying linseed oil paint to an original sash window frame.

Silicate paints can be used for external masonry, but think twice before covering original surfaces as this is invariably difficult to reverse.

When using linseed oil paint, remember:

- Bare wood should be primed with one coat of warmed, purified, raw linseed oil.
- A number of coats will be required and each must thoroughly dry before the next is applied.
- The paint is slow to dry in cold and damp conditions, so its application during the autumn and winter is not recommended.
- Faded colours can be revitalised with a coat of raw linseed oil or a single coat of fresh paint.
- There is no need to remove previous coats when applying fresh coats in the future.
- Linseed soap is used to clean hands and brushes.

TOP TIP: FIRE RISK

WARNING: If you use rags to apply or clean up linseed oil, beware of the risk of fire as they can spontaneously combust. Always dispose of them in an airtight container away

from the building.

Silicate paints
Useful for: external wall surfaces in exposed locations

Highly durable and VOC-free, silicate paints offer a degree of vapour permeability. Being water-, alkaline- and mineral-based, they are mould resistant. The paint soaks into substrates such as brick, stone, concrete, pebble dash, plaster and render and, when the water evaporates, natural chemical bonding of the silicate occurs. The structure of the paint allows the passage of vapour, but it contains hydrophobic additives that prevent the ingress of liquid water, making it suitable for certain exposed locations where wind-driven rain is an issue.

As silicate paints are not capillary open, they do not have the beauty of limewash and do not darken when they get wet. They are difficult to remove and, once they have been used, some silicate products can only be overpainted with the same type of paint.

Soft distemper

Useful for: internal walls and ceilings, particularly decorative plasterwork

Soft distemper was a common internal finish due to its low cost and ease of mixing. With a velvety, matt appearance, it is a water-based paint generally made by adding hot glue size produced from animal parts to whiting (pulverised chalk). This will create a white paint. As it dries, the glue sets and the chalk dust creates an opaque layer. To this mix, pigments dissolved in water may be added if required. It should not be confused with oil-bound or ‘washable’ distemper. These paints are also available from specialist suppliers.

Due to its water solubility, soft distemper cannot be used externally and is unsuitable for damp areas such as bathrooms and cellars, where it may become mouldy. It is an ideal paint for ornate plasterwork, as it can be washed off before redecorating, thus preventing a build-up of layers that would otherwise spoil the sharpness of original detailing. Despite its beautiful texture, soft distemper has largely gone out of fashion, due to the

availability of products such as clay paints, which are more durable and easier to apply.

Proprietary ‘soft distemper’ is available ready made in tins. It is advisable to check the ingredients and additives before you buy, as true soft distemper has a very limited shelf life.

Eco paints are also available for woodwork, but check their suitability for steamy rooms such as bathrooms.

Modified lime paint
Useful for: internal and external walls

Nanotechnology in the form of graphene fibres is used to produce natural paint products with enhanced performance. Adding nano particles of graphene helps the paint absorb into the substrate to which it is applied, improving adhesion while providing increased flexibility, strength and uniformity to the product.

The main constituent of these interior and exterior paints is lime and the basic form of white paint has few additives, so it offers good breathability. Paints containing graphene can be applied to a variety of substrates; primers are required.

As with many modern paints, the long-term performance of these products is unknown and they have not undergone specific testing or evaluation in the historic environment.

Choosing paints checklist

When selecting paints and finishes, always try to consider their environmental credentials as well as their suitability for the task. Read the label carefully and, if necessary, speak to the manufacturer's technical department to fully understand the ingredients and properties of the product.

- Does the coating need to be breathable for the situation in which it is to be used?
- Is it compatible with the substrate?
- How easy is it to maintain: is the finish wipeable or washable?
- Will it be durable, so repeated re-coating and maintenance in the future is avoidable?
- How well does it cover, and how many coats are required to give complete coverage over another colour? What is the coverage per square metre?
- How quickly does it dry? Will longer drying times be a problem?
- Is the product biodegradable?
- Is the packaging recyclable or biodegradable?
- Does the manufacturer or supplier take back surplus product to avoid it going to landfill?
- Are VOCs present and, if so, is the level high?
- Are chlorine preservatives or hormone mimics present?
- Does it contain titanium dioxide?

Some eco paints have a patchy appearance; this can look beautiful in a vernacular interior, but may be inappropriate in others.

Other eco paints
Useful for: many internal and external applications

A wide variety of good-quality paints with eco qualities is now available from specialist paint manufacturers, including emulsions and products with gloss and eggshell finishes.

These have a range of characteristics and ingredients, including plant and mineral pigments, and some claim to be breathable. Before buying, closely question the supplier and obtain a full data sheet listing the ingredients and properties, especially when balancing the needs of the building with environmental concerns.

Limewash has been used to finish these walls, as the masonry and lime plaster is still in the process of drying out. The blotchy effect gives a unique character to the finish, and the pale, subtle shade reflects the light from the window, reducing the need for artificial light.

Cleaning-up

- With water-based paints, remove as much paint as possible from tools and brushes before washing under the tap.
- Never pour paint down the sink. Even paints composed of natural ingredients can harm aquatic life.
- Natural paints containing biodegradable ingredients can be left to dry out and then added to the compost heap.
- Take excess paint to a paint collection point.

COLOUR AND LIGHT

Historically, dark colours were used in many interiors, so it is important to decide whether you are going to opt for a traditional scheme or something more contemporary. This has a direct bearing on energy use. Light colours, and those with a sheen or gloss, make a room look and feel lighter, brighter and more spacious. Consequently, the need for artificial lighting is reduced, lights can be turned on later in the day and lower output lamps may be used.

10 | ENERGY, AIR AND WATER

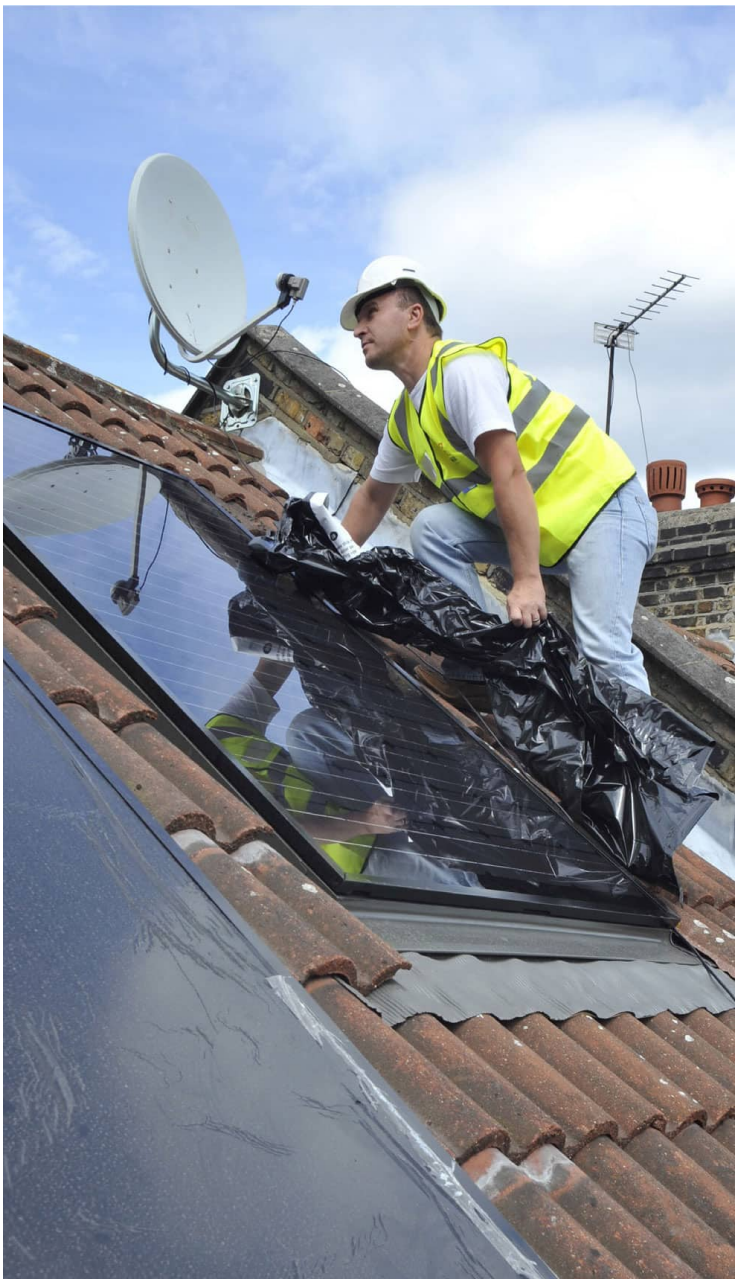
Balancing heating, water-saving, ventilation and energy-generating technologies with the needs of an old house is not always easy. Thought must be given to the practicalities of ensuring that any potential gains are worthwhile and not at the expense of the building's beauty, structure or historic fabric.

Locally gathered timber has long been burnt in hearths, windmills and watermills employed renewable energy for industry, and buildings were orientated and designed to maximise the use of sunlight and wind. Today, putting solar panels on the roof may be perceived as a very visible sign of being green – but it is certainly not the most important first step.

Quick wins and low-impact gains, such as secondary glazing, loft insulation and the use of energy-efficient lighting and appliances, significantly reduce the energy consumption of an old house. Wherever possible, fabric-first measures should be a priority – but there must be a balance between conserving the environment and conserving the fabric of an old building. Careful consideration should be given to major interventions such as wall insulation, especially if renewable energy is available to offset heat losses.

The health of the building and its occupants is essential, so thermal insulation, airtightness, ventilation, heating and energy consumption must be considered collectively to ensure that the various measures do not counteract one another. Water use within the building should also be managed. Achieving all of these things is sometimes challenging in an old house and it is important not to rush in with quick-fix solutions. Consider the implications for the building, and whether planning or other permissions are required, while bearing in mind the potential for technology to improve energy efficiency and comfort.

Sustainable energy is not a new concept – this Dorset mill both generated and employed renewable power.



Technologies including solar panels are used in conjunction with old buildings for energy generation.

HEATING

A sensible level of heating is essential, although the minimum acceptable temperature will vary from one occupant to another depending on their lifestyle and physiology. Internal temperatures below the mid teens could result in soft furnishings smelling musty and mould forming on cold surfaces. Such environmental conditions are bad for human health and

temperatures should be increased accordingly. For elderly or sedentary occupants, 18ºC is considered a minimum temperature for health in winter, supplemented by an additional heat source in the main living area where necessary. In terms of wellbeing, the most important factor is relative humidity (RH), which should be between 50 and 70 per cent for healthy living conditions. This can be adjusted by balancing occupant activity with ventilation and heating.

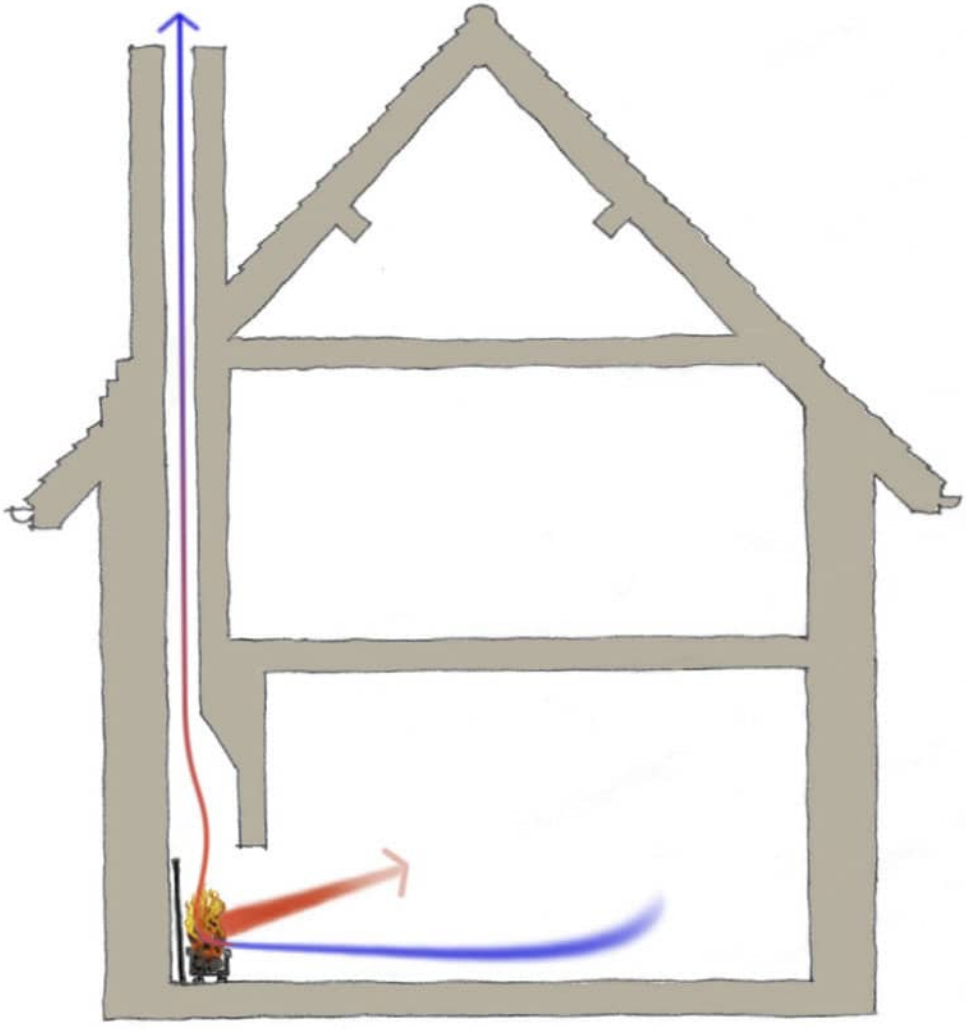
Heating systems use a combination of conduction, convection and radiant heat. The degree to which any of these means of heating is employed will affect your comfort and the efficiency of the house. In reality, the most effective way of heating many buildings is to use a combination of different methods, sometimes in conjunction with renewable energy systems.

Later fire grates were designed more efficiently to maximise radiant heat output and minimise draughts.

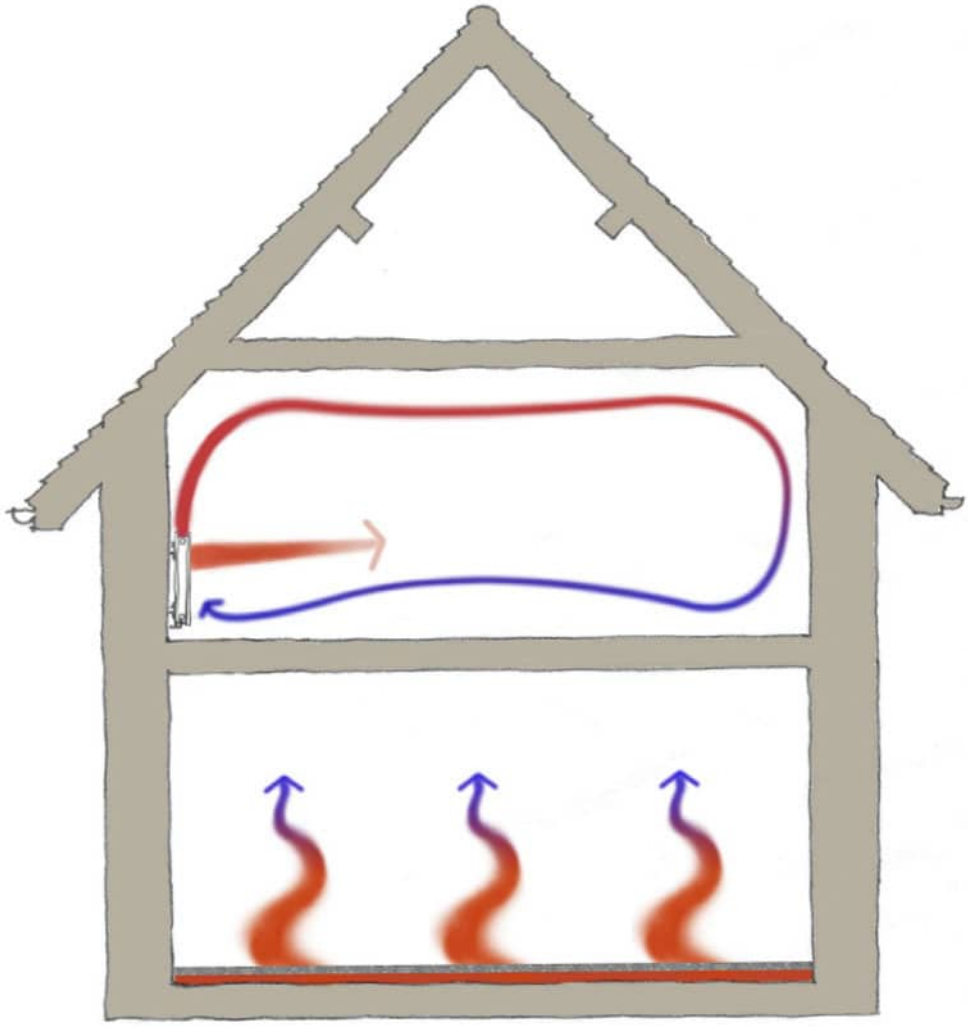
Open fires

Open fires were once the main source of warmth, giving off heat through thermal radiation, but they are a very inefficient method of heating. The performance of open fires is dependent on a number of factors; in the case of inglenooks, an iron fireback is important to radiate the heat forwards. In the past, movable screens, high-backed chairs and settles were used to retain warmth around the area of the fire.

An open fire causes a draught as air is pulled through the room and sucked up the chimney through convection (See Air leakage, shown here). This is partially countered by the psychological warming effect of seeing the glow and flames of a fire. Some secondary warming occurs because the surrounding masonry is heated by the flue gases rising up the chimney.



A traditional open fire radiates heat but creates draughts.



The lower floor has underfloor heating, providing a gentle, constant heat. On the upper floor, a radiator gives off convected and radiated heat.

Every open fire needs a working flue, but these are a significant source of heat loss.

To be efficient, radiators must be correctly sized.

Radiators

Warm to the touch due to conduction, radiators radiate some heat but most of the heat is convected upwards and hits the ceiling before falling as it slowly cools. This makes the upper part of the room hotter than the lower part, and causes a draught because the air is constantly moving; as a result, you tend not to feel as warm as might be expected. The problem is exacerbated in many older houses because of high ceilings.

Radiator systems generally need temperatures of over 55ºC to provide sufficient warmth. Low-temperature radiators may be used for situations where this is not achievable – for example, where heat pumps are being used. Radiators vary hugely in quality and design, so should be chosen carefully to be visually appropriate and to ensure that their performance will match requirements.

The default position for radiators has tended to be below windows, as their convected heat warms the cool air coming through the glazing and because the space beneath a window is not generally used for placing furniture. Where a curtain is then fitted above the radiator, most of the convected heat tends to disappear behind the curtain and out of the window, particularly where the window is not airtight. In these cases, a foil heat reflector should be fixed behind the radiator and a shelf above, with the curtain sitting on top. Inevitably this restricts the curtain length. In some instances, it may be sensible to move radiators to internal walls.

Bear in mind that radiator cabinets and covers trap heat and reduce the radiator's efficiency if they are not designed correctly with well-positioned vents. Thermostatic radiator valves must have a good flow of air around them and should always be outside any enclosure so that they can read the room temperature.

Underfloor heating (UFH)

Relying mainly on radiant heat, both electric and wet (hydronic) underfloor systems are available. These employ either loops of pipe or heating cables, sometimes in the form of mats, to distribute heat evenly across the whole floor. UFH provides an extremely gentle and constant heat and, from an aesthetic and interior design perspective, is ideal for old buildings because it is hidden. The downside is that it is the most invasive system to install, as it has to be laid into the floor and, to prevent heat being lost into the walls and sub-floor, it is essential that the perimeter and underside of the heated floor are well insulated. If old floors and other historic fabric is present, UFH is unlikely to be an option.

Where a floor has to be replaced or a concrete slab is being dug up, UFH may be a good choice (See Solid floors, shown here). When laying a solid floor, the UFH cables or pipes are generally fixed to the floor insulation and a concrete or lime screed is laid over them. The floor finish is then laid over this. Alternatively, electric heating mats offer a less invasive option as they are laid directly over existing floors but, for maximum efficiency, they should include a layer of insulation underneath. They are best suited to being covered by permanent floor finishes such as natural stone or ceramic tiles.

UFH systems often include trays such as this to make installation easier, but these should not be used on breathable floors such as limecrete.

Although it is not as effective due to lack of thermal mass, UFH can be incorporated within suspended timber floors.

With wet systems, a variety of installation methods are used including the use of aluminium spreader plates that are fixed to the joists and have preformed grooves to accommodate the pipes. Good insulation beneath is crucial to prevent heat from being lost into the sub-floor. Floorboards or other finishes can then be laid in the conventional way.

Electric heating cables are also suitable for suspended timber floors. Follow the manufacturer's directions and ensure that the correct insulation method is used to prevent overheating.

Infrared heating

The principle of radiant infrared heat is that it warms objects, including people, rather than air. This makes it beneficial in buildings that suffer from

draughts and poorer insulation or, since the heating effect is relatively quick, where heat is needed intermittently. It is particularly useful for improving comfort levels for elderly or sedentary occupants. The electric panels do not have to look like radiators: they can take the form of mirrors or pictures and may be wall or ceiling mounted. Infrared heaters are also available for larger spaces, such as barn conversions.

Infrared heating panels are often installed on ceilings.

CENTRAL HEATING

Overhauling an existing central heating system often improves its efficiency. Check that radiators are reaching full temperature right across their surface, locate the source of noisy pipes and pumps, check that thermostatic radiator valves and room thermostats are working and ensure that radiators and pipework are correctly sized. Where necessary, have the system power flushed to remove sludge, bearing in mind that this may result in leaks at any weak points. It is also worth considering adding an inhibitor to protect against corrosion and limescale.

Which fuel?

There is no one-size-fits-all energy solution although, from an environmental perspective, renewable energy should always be favoured. What works in a rural situation may not be practical in a city and vice versa. Mains gas is often seen as the most efficient and cost-effective solution but, because it is a fossil fuel it pollutes, so electric systems are regarded as preferable. In rural locations where mains gas is unavailable and there is reliance on oil or LPG (liquefied petroleum gas), renewable energy is an obvious and potentially cost-effective alternative.

When thinking about energy security, it makes sense to have more than one source of energy available; this may include a wood-burning stove. There are other advantages to having more than one means of heating. For example, an air source heat pump might supply low-level heat while a wood-burning stove or radiant infrared heating raises the temperature and level of thermal comfort during occupied periods.

TOP TIP: WATER SOFTENING

In hard-water areas, limescale is likely to corrode appliances and may build up on the heat exchanger of your boiler, impeding its efficiency. Using a water-softening device can help prevent these problems.

Before specifying a new boiler, make sure your home is fully insulated, airtightness has been improved and everything else has been done to increase the efficiency of the building's fabric. This fabric-first approach means the new boiler can be correctly sized, otherwise it may be unnecessarily large – and consequently inefficient – for the job.

If you are installing a solar thermal system or considering this for the future, check that it can work with the boiler. In the case of boilers that have a separate hot water tank, both the boiler and tank will need to be compatible with the solar system. Boilers require a flue and sometimes a condensate pipe running to an exterior drain. Think carefully about how these will affect the building's external appearance and try to ensure that they emerge on an inconspicuous elevation. It may be possible to use a redundant chimney stack or other void, although strict rules apply to the installation and inspection of flues carrying combustion gases.

Boiler flues and vents easily spoil the facade of a building, so think carefully about their position when planning interiors.

Heating control

Good-quality, properly set up and correctly located heating controls dramatically increase operating efficiency while maintaining comfort. Wireless thermostats and control systems help avoid the need to run cables to various devices and will mean that equipment can be positioned discreetly, without damaging the building's fabric.

Dividing a building into distinct heating zones covering different heating needs increases the energy efficiency of the system. This is particularly

relevant in large houses, where only a limited area might be used regularly or distinct areas may be used at different times of the day. There are various ways of accomplishing this, but a relatively easy method is to use wireless thermostatic radiator valves and a suitable control unit. In some situations, additional pipework may be required.

TOP TIP: MINIMISING DAMAGE

A thermal-imaging survey of the floors of a house with the heating on and hot taps running will reveal where the pipework is for both heating and hot water. These can then be marked on the floor so that any new pipework can be planned to follow existing pipe runs, minimising any unnecessary lifting of floorboards and notching of joists.

CHIMNEYS, FLUES AND FIREPLACES

An open fire or a stove can be a good way of creating residual heat in the mass of a building, and should help reduce internal moisture levels. Where flues are to continue in use, it is essential to have them checked regularly. Always consult a specialist to establish the suitability of your chimney for any type of heating device that relies on combustion.

Background ventilation is vital where combustion is occurring. Originally, this was provided by draughts through leaky windows and doors but, once these have been blocked to make the building more airtight, other means of ventilation must be provided. One option is to fit an air vent in front of or beside a grate to create a draught at the point where it is required. If such a vent is fitted, make sure that it can be temporarily closed to prevent draughts when no fire is lit.

Chimney draughts

Chimneys are a cause of heat loss and draughts, particularly when not in use. There are various ways of countering these as well as muffling wind noise and stopping wildlife and debris from falling down the flue. Register grates with a flap at the back were invented for this purpose. Inglenooks can be fitted with canopies to produce a more efficient burn and reduce smoke. Such canopies usually incorporate a flap that is closed when there is no fire.

Where these solutions are not available, it is worth considering a draught excluder that is temporarily inserted in the bottom of the flue when the fireplace is not in use. These come in a number of forms and it is important to use the one that is most suitable for the shape, size and type of opening:

- Wool draught excluder with a handle, which allows it to be easily wedged in place at the base of the flue.
- Chimney umbrella that opens to block the flue. It also collects fallen debris, rain or hailstones into the canopy.
- Chimney balloon or chimney pillow, which is inflated within the flue with a pump. These are designed to be left in place for longer periods, as they take effort to inflate and deflate.

It is important to maintain a small amount of ventilation to the flue in order to avoid condensation so, if draughtproofing devices are to be installed for any length of time, it is advisable to trap a short length of tube against their side to prevent the flue from being totally sealed. In all cases, it is vital to remember to remove the device before lighting a fire.

Wool draught excluder.

Chimney umbrella.

Chimney balloon.

Sealing flues

When sealing a flue permanently, give careful thought to ventilating it to prevent damp and rot occurring. This is generally achieved by installing vents at both the top and the bottom to ensure a free flow of air through the length of the flue. Often the vent at the bottom of the flue is, by necessity, installed at the base of the chimney breast within the house, but this inevitably leads to air leakage. Where a chimney is on an external wall, this

problem can be avoided by installing the vent at the base of the chimney externally. Special caps, often referred to as ‘pepper pots’, are available; these fit onto the top of the chimney and incorporate vents but do not allow rainwater to penetrate.

Another option is to fill the flue. This is a reversible solution that provides a high level of insulation. It offers the advantages of preventing both thermal bridging through the chimney stack and sound transmission down the flue. The flue must be free from damp and should first be professionally swept and checked. The opening at the base is then blocked and the entire length of the flue is filled from the top with a suitable granular insulation, such as foam glass beads. The chimney should then be capped. Capping a flue or filling it is inadvisable where other flues in the stack remain in service, as there is a risk that flue gases may leak into it and then out into habitable spaces.

The redundant flue to the left has been capped, but a vent has been fitted to the stack lower down to ensure flue gases do not build up should they escape from the adjoining flue. The right flue, which serves a wood burning stove, has been lined and fitted with a rain-cap and bird-guard.

Wood or pellet stoves

Large fireplace openings such as inglenooks are notoriously wasteful of energy and any fire that is lit may be only 20 per cent efficient. One way of improving efficiency, while maintaining the character of the opening, is to install a wood- or pellet-burning stove. As well as heating a single room, some stoves may be fitted with a back boiler to provide hot water, or can be linked up to your central heating system as well as to solar thermal panels.

If buying a stove, make sure it is at least 80 per cent efficient and is designed to reduce emissions of particulate matter (PM). The most eco-friendly stoves are capable of reducing PM by 90 per cent compared to an open fire, and by 80 per cent compared to older stoves. Pellet stoves can be particularly efficient but require a source of electricity to operate, so they do not provide the level of energy security offered by ordinary stoves.

When choosing a stove, make sure the calculations for its output are based on realistic building performance data. Adopting overly pessimistic U-values will encourage the over-sizing of stoves and a waste of energy (See How do walls compare?, shown here).

Wood-burning stoves are a good way of improving energy efficiency in large fireplace openings such as inglenooks.

Installing a wood-burning stove in a relatively airtight house can be challenging. When the stove is lit, the mechanical ventilation employed within the house may result in toxic gases being drawn into the room because the air pressure inside the building is lower than outside. Where this is likely to be a problem, it is vital to seek the advice of the supplier and installer. In some cases, it is possible to use a stove that brings in air from outside the building. Using external air has the added advantage of eliminating draughts and adds to the stove's overall heating efficiency.

Before installing a stove, the chimney must be inspected with a camera, appropriately lined and insulated to prevent the risk of fire. During installation, a metal register plate is installed to seal the gap and minimise draughts between the stove's flue and any larger existing opening.

Fire risks

Any open fire, stove or chimney is a potential fire risk. In old buildings, adjacent timber – including embedded joists and fireplace lintels – and

other materials can easily be set alight, so always employ experts and have your flue checked regularly.

Badly installed stoves in existing fireplace openings are a major concern. Research highlighting the risk of using wood-burning and multi-fuel stoves in thatched properties has resulted in a recommendation that they should not be used in these buildings; they present a greater risk to thatch than other forms of heating, including open fires.

Wood-burning stoves present a risk in thatched houses; chimneys must be properly lined and regularly checked.

Burning wood

Burning wood produces particulate matter (PM), but the amount depends on how the wood is burnt. To minimise emissions:

- Wood must be dry. Wet logs produce far more PM than dry logs and energy is wasted burning off the water so the heat output is lower. Never burn wood that has a moisture content over 25 per cent.
- Ensure a good air flow to the fire. Wood generates more smoke when the supply of oxygen is poor so, as well as creating emissions, it will cause a sooty build-up in the flue, which can be a fire hazard.
- Allow wood to season in a covered but well-ventilated area outside, so that moisture is driven off. Hardwood tends to take longer to dry out than softwood, but you should generally leave it for one or two years.

To burn efficiently, logs must be well seasoned.

Warning systems

Carbon monoxide is a toxic gas that you cannot see, smell or taste. The product of inefficient or incomplete combustion of fossil fuels, potential generators are cooking appliances, boilers and open fires. Its presence in a room indicates a potential problem that should be rectified immediately.

If you are burning any type of fuel, carbon monoxide detectors should be fitted. Smoke alarms and heat detectors – preferably hard wired – are also vital in all houses, but especially where open fires and chimneys are in use; it is often worth installing an extra sensor in the roof space. If you have a monitored intruder alarm, it is often possible to include carbon monoxide and fire detection under the contract so that the emergency services would be alerted to a potential problem, even if you are not at home.

INSTALLING SERVICES

Installing modern services in old buildings is potentially extremely invasive. Damage to the fabric and appearance of the building is a concern, so never leave the planning of an installation to chance. Think ahead and discuss the issues when the work is quoted and with the installer on the day.

- Plan routes for cables and pipes to minimise damage. Use existing service routes and consider redundant chimney flues, as they can sometimes offer a viable passage from the top to the bottom of a building.
- Avoid chasing into historic surfaces wherever possible; it may be better to run a conduit on the surface.
- Take care lifting and replacing floorboards (See Insulation of suspended floors, shown here).
- Use wireless thermostats and other wireless devices to save the need for cable runs while also reducing installation costs and improving the efficiency of systems.
- Repair penetrations made in the building's fabric when installing services and seal against air leakage.
- Take particular care to ensure back boxes for power outlets and light switches are airtight and do not penetrate membranes (See Sockets boxes, shown here).
- Ensure equipment is easily accessible for maintenance.

TOP TIP: CABLE FIXINGS

Fixings for cables should be made into the mortar rather than into the face of bricks or stones. Any damage can then be patched relatively easily or repointed if the cable is removed in the future; a hole drilled into a brick is there for life. In this case, a previous fixing has permanently scarred the brick.

Installing services can be extremely invasive – a little care minimises unnecessary damage.

Joists are weakened when they are notched. Ideally services should be run through holes drilled in the centre, where they also will not be vulnerable to nail damage.

WATER AND PLUMBING

Water is a valuable and finite resource. Energy and chemicals are used to clean and pump fresh water to our homes through the distribution system and to dispose of and treat it after use. In the home there is a hidden cost: hot water accounts for 23 per cent of heating bills and is 13 per cent of the total domestic energy bill.

Old cisterns can be adapted for modern use.

Minimising water use

Old taps are notorious for dripping and leaking, so make sure that they are overhauled and washers are replaced. Traditionally, basins and baths are often large so, if replacing, consider smaller versions that require less water to fill them. When selecting taps and showers, choose flow-limiting versions; some have aerators that reduce water consumption without compromising the experience of using them.

Toilets have traditionally used much more water to flush than their modern equivalents. One way of cutting the amount of water used is to put a brick in the cistern or one of the, often free, devices offered by water companies. An important consideration when doing this, or when installing a low-water-use toilet cistern, is whether the drainage system can work satisfactorily with a smaller volume of water. Where there is insufficient fall on the pipes, the drains may become ‘dry’ so debris might not be carried away and blockages could occur. In these cases the presence of regular rodding points becomes even more important to allow future maintenance.

Hot water systems

Ideally, the layout of a house should be designed so that the plumbing system is as compact as possible, with bathrooms and other points of water use grouped close together. In old houses this is often not possible, and hot water may have to travel some distance from the boiler or storage tank. These long lengths of pipe, where cold water has to be run off until the desired temperature is reached at the tap, are known as dead legs. The problem can be mitigated to some extent by ensuring that these pipes are of the minimum diameter acceptable and are well insulated to slow the cooling of the water in between use.

The problem of dead legs is sometimes addressed by installing a recirculating system, where the hot water is pumped around a well-insulated main distribution ring, with very short lengths of take-off pipework to the point of use. This offers the convenience of almost instant hot water. The benefits in terms of energy savings are much debated because of the need to pump the water and reheat it due to cooling as it passes round the system. These issues can be addressed to a certain extent through the use of timers, so that water is pumped only at certain times of the day. A simpler, and more energy-efficient, solution might be to use tankless point-of-use water heaters. In kitchens, it may be worth considering installing a boiling water tap to supply instant hot water.

Pipe insulation

Hot and cold pipes should be insulated to prevent both freezing and heat loss. Pipe insulation must be fitted carefully to ensure that every bit of the pipe is covered, including joints, bends and hard-to-reach sections.

Although it is fiddly and time-consuming, it is an unskilled job – so suggest to your plumber that you do it yourself to save money and ensure that it is done as you want.

TOP TIP: RETAIN THE PAST

Antiquated heating and water systems form part of a building's history. Where they are being replaced, pause for a moment to record what is being removed by taking photographs and making notes. If it is practical to do so, leave the most interesting examples of radiators, pipework and electrical fittings in situ, even if they are no longer serviceable.

Grey water recycling

Grey water systems store basin, bath and shower water for flushing toilets. Although they may be worth considering when undertaking major retrofits, the systems are normally reserved for new-build situations, as they are difficult to incorporate into existing structures.

Rainwater harvesting

Rainwater harvesting saves water while helping reduce rainwater run-off and flooding. A water butt to collect water for garden use is the simplest

option. More sophisticated systems allow rainwater from roofs to be stored and used for flushing toilets, washing cars and even for washing machines. These systems are easier to install in existing buildings than grey water systems, but they do involve extra internal and external pipework, so care needs to be taken to minimise damage to the building’s fabric and appearance.

Space is required for a storage tank either above or underground. Some systems employ a header tank in the loft to which water is pumped from the underground tank. Not all roofs lend themselves to rainwater harvesting, especially if there are many slopes and downpipes that make capturing the water difficult. The system needs to be sealed to ensure that the water does not contain excessive debris.

Water butts are an easy way of harvesting rainwater, but make sure they are regularly cleaned out to avoid the formation of legionella bacteria, especially when pumping and spraying water from them.

VENTILATION

‘Build tight, ventilate right’ is the key to retrofitting a home so that it is both energy efficient and healthy. Ventilation ensures good indoor air quality (IAQ) by removing harmful pollutants and moisture, which could otherwise result in condensation and mould growth. To ensure these goals

are met, adequate fresh air must enter the building while stale air is extracted by natural or mechanical means, or a combination of both.

Studies show that both new and existing homes are increasingly underventilated. This is due to a combination of poorly designed and installed ventilation systems, and a desire to save energy by closing vents or not using the ventilation systems. Whatever system is chosen, it is vital that it is properly designed, installed and maintained. Seek out local, specialist engineers and installers who will both design and fit.

No two old houses are the same. Ventilation methods must be tailored to suit the specific needs of the building without unnecessary damage to its historic fabric. Ventilation falls into two categories: passive and mechanical. With both the key is control, to enable a balance between good IAQ, comfort and energy efficiency (See Indoor air quality and ventilation, shown here).

Natural ventilation

Making use of the forces of the wind and temperature differences within the building, natural ventilation is efficient and cost effective when carefully designed.

Adventitious ventilation is found in most existing old buildings that rely on accidental draughts and openable windows for ventilation. This is not a recognised design approach and is highly variable and unreliable.

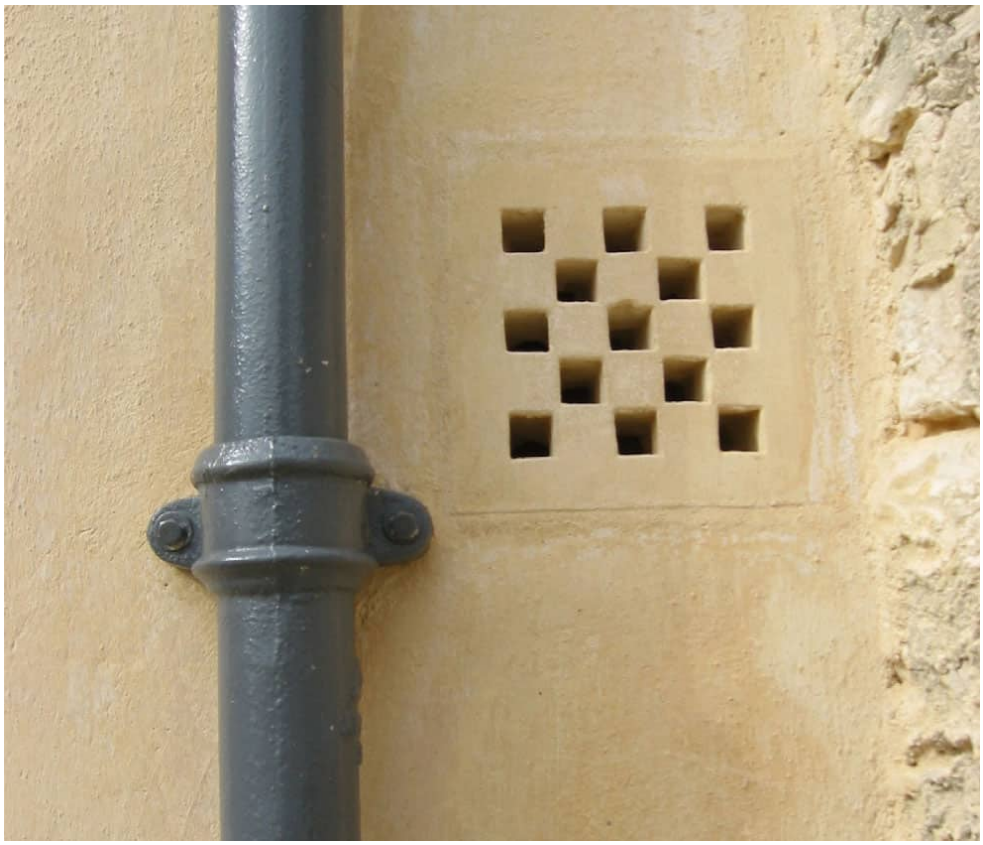
Passive stack is the most common form of natural ventilation and works in a similar way to a chimney. It relies on the movement of air resulting from the difference in temperature between the outside and the inside of the house and the effect of wind passing over the roof. The natural buoyancy of warm air causes it to rise, so cool air is naturally drawn in at low level. Stack effect is least efficient on hot days, as the pressure difference is smallest. It requires vertical ducts extending to the roof ridge with controllable vents in the ceilings of wet rooms. It will not work well on single-storey or flat-roofed buildings. Air will take the path of least resistance, so careful design is necessary; pipes within cold roof voids should be insulated.

Mechanical ventilation

Using fans, ducts and control systems, mechanical ventilation takes a number of forms but inevitably requires energy to function. Most systems extract air from wet rooms – kitchens and bathrooms – and some introduce fresh air into the living areas of the house.

In buildings with good airtightness, present thinking increasingly favours mechanical-extract ventilation systems where fans operate continuously while recovering heat from the air being extracted, as this has been shown to provide the best possible consistent air quality.

The installation of whole-house systems potentially requires major interventions. Ductwork will invariably have to be threaded through the fabric of the building and the damage is likely to be significant. In many old houses this will not be acceptable, so less invasive ventilation options should be chosen, such as the use of natural ventilation or single-fan decentralised units.



It is possible to design ventilation grilles so they are not unattractive.

Use specialist engineers to design and install ventilation systems.

Where the decision to install a centralised ventilation system is taken, think carefully about where to site the main unit. Make sure there is room for ductwork and consider noise and maintenance issues. Some units are bulky but might be accommodated in a dedicated cupboard or in the roof space, although it is essential that the unit is easy to reach for maintenance, adjustments and replacement of filters.

Intermittent extractor fans are the simplest form of mechanical ventilation, generally installed in bathrooms and kitchens. This type of

ventilation is the minimum required by building regulations. The fans usually vent directly through the wall and are either turned on manually when required or, in the case of bathrooms, linked to the light switch. Once activated, they are timed to stay on for a predetermined period after the light is turned off.

Decentralised mechanical extract ventilation (dMEV) employs individual extract fans located in each wet room that run continuously and have a boost function when the room is in use or if humidity exceeds a set level. The fans are quiet and run at low speed, drawing only a few watts each.

Ventilation units are sometimes bulky, so thought needs to be given to siting them.

Mechanical extract ventilation (MEV) is usually a centralised extract fan located in a loft or void, with ducts to draw moisture-laden air from multiple wet rooms. The extracted air is normally discharged to the outside via a single duct. The system runs continuously but has a boost function when activated either manually, by a light switch, or as a result of raised humidity levels. Units can be noisy, so consider adding acoustic dampers to the ducts. A condensate drain, run to a waste pipe, is required.

Mechanical ventilation with heat recovery (MVHR) extracts damp air from wet rooms and uses a heat exchanger to remove heat that would otherwise be exhausted to the outside. This heat is then used to warm a similar volume of fresh, filtered, incoming air, which is distributed to the living areas of the house.

To be efficient, MVHR systems need to be used where air leakage from the building is minimal – otherwise the extraction will draw in cold, outside air, outweighing the value of the warmed air being introduced. The more airtight the building, the more effective MVHR will be – and, while these systems work well in new homes built to achieve high levels of airtightness, retrofitted old houses do not always reach the required standards. The level of airtightness at which MVHR starts to be effective is 3 $m^3/hr/m^2$ at 50 Pa, or 3 ACH (air changes per hour) (See Airtightness test, shown here).

Single-room heat recovery fans provide an alternative to whole-house systems and are a good way of tackling a room with a condensation problem. These avoid ducting and are relatively simply to retrofit through a hole in the wall, allowing standard wet-room extract fans to be easily replaced.

Background ventilation

To replace the air being removed from the building, background ventilation is vital. Even after a retrofit many old houses are not totally airtight, but relying on this uncontrolled air infiltration is not good practice. Fresh air should be introduced into the building in a controlled way through trickle and other vents in external walls that can be opened and closed as necessary.

Most vents are manually operated, but passive, demand-controlled inlets and outlets are available that, rather than requiring electricity, are worked by mechanical sensors measuring humidity or temperature, thus minimising heat loss.

Ductwork

Ducting routes and penetrations through walls and ceilings must be carefully considered, both to minimise the impact on the building and to ensure optimum performance for the ventilation system. It is sometimes possible to use systems with small-bore ducting to make installation easier, but where significant original fabric is likely to be damaged or destroyed, other solutions should be chosen.

The specification of the system is crucial and, wherever possible, should be undertaken by a ventilation specialist. All ducting must be supported along its length to prevent sagging and abrupt bends; long runs of ducting should be avoided wherever possible. Rigid, smooth-sided ducting should be used. Flexible ducting is unsatisfactory, as it can restrict air flow and may be noisy due to its ridged sides and the fact that it is often compressed around bends and between joists. All penetrations through the building’s external envelope must be sealed to prevent air leakage.

Intermittent extractor fans are the simplest form of mechanical ventilation.

In cold spaces, ductwork should be insulated with closed-cell material to avoid condensation, reduce heat loss and cut noise. One of the biggest problems with ductwork is where joints are poorly sealed, causing the system to be inefficient and risking moisture escaping into the fabric of the building, particularly loft spaces – so do make sure that all joints are sealed as recommended by the manufacturer.

Maintenance

Air filters within ventilation systems must be cleaned regularly and may need to be replaced periodically to maintain efficiency and prevent a build-up of pollutants that could be recirculated into the house. Fans should also be checked periodically.

This clogged MVHR filter will affect the performance of the system.

LIGHTING

Although natural daylight is healthy and energy free, and so should be used wherever possible, artificially light is an obvious necessity; it is worth remembering that, as we age, we need more light. LED lamps offer good-quality illumination and require a fraction of the energy of the incandescent lightbulbs that have been in use since electric lighting was first installed in homes.

There are a number of considerations when employing LEDs in old buildings, especially the quality and colour of light they offer. Traditional tungsten filaments provide a spectrum of light not dissimilar to that of fire or candlelight. As a consequence, the colour of light from an incandescent tungsten lamp tends to feel natural in historic interiors. Many LEDs do not have this characteristic, so choosing a lamp with the right colour temperature is crucial. As a guide, an incandescent lamp has a warm colour temperature of around 2700˚K while daylight, which is much colder, is 6000+˚K. LEDs are available across this range so, in many cases, warm LEDs are used in living and bedroom areas while cold LEDs are employed in kitchens and bathrooms. Some LED lamps designed to work with smart technology are adjustable from cool to warm; others allow colour-changing capability across the spectrum.

Unlike traditional lamps, where the light output was described in watts, the brightness of LED lamps is given in lumens. Very roughly, a 500–700-lumen LED lamp is equivalent to the light output of a 50W halogen or 60W tungsten filament lamp.

Another consideration is the lamp's colour-rendering index (CRI), as this will affect the appearance of interior decor and artwork, so always look for a CRI of at least 80. Where an LED lamp needs to be dimmed, you must buy a dimmable version and ensure that the dimmer you are using is compatible. If in doubt, seek the advice of a registered electrician.

Where you have historic fixtures and the light source is visible, the shape of the lamp is important. Normally, clear lamps were used in early electric light fittings and many had a distinct shape; the equivalent LED lamps rarely have exactly the same profile, but it is worth searching.

When installing lighting, wireless light switches save the need to chase walls, which is damaging to the fabric of an old building and can be expensive. A receiver fitted near the light fitting picks up the signal and activates the light. Some switches do not require batteries, as they generate a small electric current every time they are turned on or off.

Incandescent lightbulbs were the traditional means of lighting.

A wide range of LED lamps is available.

Some LED lamps require separate drivers that supply a controlled voltage to ensure they always operate in their optimum range.

To avoid lights being left on when rooms are unoccupied, PIR (passive infrared) occupancy motion sensors are an alternative means of control and are particularly suited to cloakrooms and corridors.

Exterior lighting

Think carefully about where to site external lighting to minimise damage to the building's fabric and its aesthetics, both during the day and when it is on at night. Light pollution is a major concern, so avoid fittings that spill light into the sky or neighbouring properties wherever possible.

PIR motion detectors will help minimise the time that lights are lit, cutting both light pollution and energy use. For the same reasons, choose floodlights with the minimum brightness lamp necessary to achieve the required level of illumination. One way of minimising the impact of cables is to use self-contained solar-powered lamps. Floodlighting of buildings needs to be treated sensitively and is always best linked to time switches that are set to avoid overuse.

Exterior light and PIR sensor.

Recessed light fittings

Recessed downlighters are often incompatible with old ceilings, as they are likely to weaken their sometimes fragile structure, compromise the integrity of the ceiling's fire protection and allow air leakage and draughts. Water vapour is also likely to pass through, particularly in bathrooms, shower rooms or kitchens. Unless they are indispensable, consider replacing recessed fittings with a surface-mounted alternative.

Where these fittings are installed, they should meet the necessary standards and either be suitably fire rated or have fire hoods fitted. These are difficult to seal against a lath-and-plaster ceiling and must be installed carefully to avoid the lamp overheating. For the same reason, insulation must not be placed in the ceiling void around downlighters.

Consider the implications before fitting recessed downlighters.

Try to combine installing systems such as solar photovoltaic panels with other roof work.

When installing solar photovoltaic panels, an inverter has to be housed inside the house.

ENERGY GENERATION

Technology is constantly improving and there is plenty of information about the different energy generation systems available. It is worth spending time looking at the options and speaking to a variety of suppliers. In the context of old buildings aesthetics tend to be a key concern, but potential damage to the building's fabric and the ability of the structure to support the weight of the technology are equally important. The need for space to house the associated equipment within the building must also be taken into account, along with the impact on buried archaeology when digging trenches for

pipes or cables, and the disturbance of wildlife such as bats (See Wildlife and buildings, shown here).

All systems are likely to require maintenance at some point, so think how this will be achieved and whether it will be possible to incorporate future changes without affecting the building. Equipment has a finite life, so remember that it will have to be replaced in the future. Equally, the building fabric behind or beneath may need to be repaired. For example, solar panels might have to be removed to deal with a leaking roof.

Evacuated solar thermal tubes being installed in a hidden roof valley.

A good time to think about installing roof-mounted panels is when the roof has to be re-tiled or slated, because combining the jobs is likely to be cheaper, less damaging and far less disruptive than adding the technology later.

If there is an aspiration to utilise solar panels or other technologies at some point in the future, consider where the cable or pipe runs may go and

whether, for example, it is necessary to re-configure the incoming electrical supply or the main distribution board.

Often several types of technology are installed to provide a building's energy requirements. Where this is the case, look at the scheme holistically to ensure the best all-round solution, both in terms of their energy output and their combined impact on the building. Always try to procure systems and designs through a single installer or use compatible products from the same supplier to avoid problems with operation or performance.

Solar photovoltaic (PV) systems

Converting sunlight directly into electricity, PV systems can be installed as panels over the existing roof or be integrated within the roof covering. Integrated systems tend to be less visible, but will result in the loss of historic fabric. Another disadvantage with some integrated PV products is that they are made to the dimensions of modern, machine-made tiles and slates, so they are only suitable for re-roofing projects using new materials.

PVs are generally fairly low maintenance and tend to be a less expensive option than solar thermal systems. Compared with installing solar thermal, there is potentially less danger of damage to the building's fabric as, rather than pipework, PVs require only cables to be threaded down through the structure.

Solar thermal systems

There are two types of solar thermal system: flat plate and evacuated tube. Flat plate collectors tend to be more robust and less visible than evacuated tube systems when installed on old roofs. Both provide domestic hot water but do not generally contribute to central heating. They require a large hot-water storage tank or thermal store. Where a new heating system is being installed and solar thermal is being contemplated as a later addition, ensure you future-proof by installing a compatible boiler and tank.

Roof-mounted panels

Solar panels must be orientated to make maximum use of sunlight, so it might seem that they need to be placed in a highly visible position, possibly detracting from the building's appearance. This is not always the case. Many buildings have hidden areas – for example, below parapets or between multiple roof slopes, as is the case with 'M'-style or double-pitched roofs. The roofs of outbuildings or a freestanding ground-mounted array within the garden or grounds of the house are alternative options. In all cases, consider the impact of shading from parapets, chimneys and other features, as this will affect output. There are a number of further considerations:

- What is aesthetically most appropriate for the type of roof covering? Panels vary in design, texture and colour and are generally reflective. A particularly visible element is the frame, which is often unpainted aluminium. The smooth surface of panels looks particularly incongruous on roofs where slates or stone tiles are laid in diminishing courses, or where pantiles or other irregular and undulating surfaces are present.
- Will the panels be fitted on roof or in roof? On-roof panels sit above the roof covering, so less of the building's fabric is disturbed and the installation is reasonably reversible, but they tend to show more. With in-roof or integrated panels, the roof covering is removed and replaced by the panels. Although this means greater disturbance and possible damage to the roof timbers, there is less additional loading because the lack of tiles or slates partly compensates for the added weight of the panels. If you are re-tiling anyway, this solution may save money as less of the roof covering is required. Integrated arrays generally require ventilation to avoid overheating and may have a lower output than an equivalent non-integrated system.
- Is the structure of the roof and the building strong enough to support the weight of the panels? It may be advisable to employ a structural engineer to make an assessment. Where a roof abuts another property, strengthening it could have party-wall implications.
- What are the consequences for the roof covering? It is usually necessary to drill through tiles or slates so that a fixing can be made to the rafters beneath; the roof covering will also need to be pierced to accommodate cables and pipework. Once the panels are installed, damaged tiles or slates will be hidden from view and difficult to access.
- Does the roof covering pose particular issues? The roof's surface must be stable and even, as undulations may cause problems. Fixing to thatch is not recommended due to movement over time. Lead roofs are designed to expand and contract, so the panels should be mounted on the fixed section at the top third of the lead sheet. It is advisable to replace a felt roof before panels are installed.
- Is there wildlife in the roof? Bats and some birds are protected, so take advice before starting work (See Wildlife and buildings, shown here).

Installations vary in their complexity; some are more straightforward than others.

The roof of an outbuilding provides an alternative home for solar panels leaving the historic roof uncluttered.

Some solar tiles such as these are designed to have a similar appearance to real slates.

A flat-plate solar thermal system on a sandstone-tiled roof in Derbyshire.

Heat pumps

Taking heat from the ground, water or air, heat pumps provide heating and, in some cases, hot water; certain models can be reversed to cool the building's interior in summer. Heat pumps are most efficient with well-insulated, airtight buildings. Less heat is produced than with a boiler, so they work best with wet underfloor heating systems or with special low-temperature, fan-assisted or oversized radiators.

Ground-source heat pumps circulate fluid through a long loop of pipe that acts as a ground collector. This is either buried in trenches or installed vertically in a borehole, so a relatively large site is required. A similar method is employed to extract heat from lakes or rivers. Consequently, the collection system is largely out of sight, although it is important to be aware

of the possibility of disturbance to archaeology when digging trenches or drilling boreholes. Care must be taken when digging close to walls to avoid affecting the structure's stability.

Air-source heat pumps extract heat from the air, either distributing it via a wet central heating system (air to water) or producing warm air circulated by fans (air to air).

Ground-source heat pumps involve considerable excavation.

Biomass

Biomass is regarded as carbon neutral, since the carbon dioxide produced when wood or other organic matter is burnt is roughly the same as that absorbed when it is growing. Logs, wood pellets and chips are burnt in

stoves or in special high-performance boilers that provide space heating and hot water. These boilers are much larger than conventional boilers and are generally considered to be a practical solution in larger homes and hard-to-insulate buildings where the heat demand is high. Time and maintenance are more of a concern than with other systems due to the need to remove ash and feed the boiler, although some do this automatically.

A flue is required from the boiler, so its position should be carefully considered with regard to its aesthetic impact. It may be that an existing chimney can be used, although this must be lined. Another option is to house the boiler in an outbuilding, but good access for deliveries is essential so that the fuel can be unloaded easily into a large, dry storage space. To be sustainable, biomass must be locally available.

Air-source heat pumps are more visually intrusive, but less expensive to install than ground-source pumps.

Wind turbines

To generate electricity effectively, wind turbines must be relatively large and require a clear passage of wind, unobstructed by buildings, trees or landscape. Turbines transfer the strength of the wind through any fixing, so the vibrations are likely to put a significant strain on the structure. Mounting on any part of an old building is not recommended. Noise, aesthetics and their impact on wildlife such as birds and bats must be considered.

Housing the kit

The equipment associated with energy generation – including thermal stores or tanks – is potentially bulky and heavy. Where there is insufficient room within the house, outbuildings may offer an alternative. In all situations, key considerations when planning an installation include the ongoing maintenance of both the technology and the building's fabric, the weight of the kit and the need for ventilation or flues. If floors have to be strengthened or holes cut through walls, the implications might be significant. Where solar panels, thermal stores or other equipment is remote from the main building, the connecting cables and pipes may need to be buried and the pipes heavily insulated.

Renewable technologies often require a dedicated space to accommodate the necessary equipment.

Wood pellets need to be sourced locally to be sustainable.

A log-burning biomass boiler.

A 1 kW up-wind turbine generates electricity in a coastal location.

Hydro power

The rivers feeding old watermills potentially offer the opportunity to generate electricity. When undertaking a hydro-power installation, it is important to conserve the integrity of the mill's structure, any historic machinery, the building's aesthetics and the surrounding environment. Consideration must also be given to the various legal requirements associated with the abstraction of water, the stability of the building, the space available for the necessary equipment and the potential risk of flooding.

Hydro power can involve considerable intervention in historic settings.

Where a mill is capable of working, or of being renovated to be workable in the future, ensure that a hydro-power installation does not compromise this ability. In some cases, leats, ponds and weirs will need to be repaired and these may require considerable ongoing maintenance.

ENERGY STORAGE

Storing energy for when it is needed makes sense, although it is unlikely that you will have sufficient for all your needs. With heat pumps and solar thermal panels, excess energy can be retained in a highly insulated thermal store. Energy from PV panels may be stored in a similar way by using surplus electricity to heat hot water. Alternatively, batteries integrated with solar PV systems are designed to charge during the day and then power the house in the evening.

ELECTRIC VEHICLE CHARGING

Charging an electric vehicle (EV) at home is the cheapest and easiest way to keep it topped up. Although this can be done from a standard power socket, it is not recommended on a regular basis. Specially designed chargers are safer and faster. If you are considering buying an EV,

investigate the charging options and the specific electrical requirements for EV charging points before rewiring the house. You are likely to need a dedicated electrical circuit capable of taking the load, cabling to the charging point and an earthing system that meets the necessary regulations.

CONNECTIVITY AND TECHNOLOGY

Encompassing everything connected to the internet, the internet of things (IoT) allows heating, lighting, security and entertainment systems to communicate in the home. This potentially provides the ability to monitor and control devices remotely from your smartphone, including regulating the temperature within the house, so that comfort is maintained but energy is not wasted. The savings achieved can make the payback times for these systems attractive.

To ensure good internet access is available and for the IoT to be effective, a connection is essential throughout the house. Wireless or Wi-Fi solutions are inevitably part of this and can minimise the need for cable runs. Signals can be boosted using simple range extenders that plug into power sockets. In older buildings, more sophisticated boosters or hardwired systems might be necessary due to the thickness of walls, large chimney breasts and steelwork, which may block or interfere with both Wi-Fi and mobile phone signals. When undertaking retrofits consider what is required early on, as it will be easier to install the necessary cabling. Ensure power supplies are available for routers and boosters along with direct access to the master socket of your telephone/broadband line.

COMMISSIONING

It is vital to ensure that all mechanical, electrical and plumbing systems have been properly installed and are working as intended, so each element should be fully tested and, where they are reliant on one another, they must be evaluated together. Monitoring the building once occupied and in use is part of this process and it is important to check that the energy generation/consumption, water use and ventilation flow rates meet the goals expected of the original design. The building’s fabric should also be monitored to ensure that the systems and measures put in place are not having a detrimental effect. For example, is condensation or mould growth

occurring because of poor ventilation or is joinery moving or cracking due to temperature changes (See Monitoring, shown here).

At handover, the homeowner and users should be given proper operating and maintenance instructions as well as all manuals, guarantees and other documentation. Without this essential information, maintenance is more likely to be neglected and items replaced rather than repaired.

Larger gardens provide an opportunity for ground-mounted solar arrays, while drying washing naturally outside saves energy. This array unfortunately suffers from shading during parts of the day.

11 | OLD HOUSE FOR THE FUTURE

Sustainability is about more than insulation, airtightness and being energy efficient. It is not even just about buildings. It is a way of thinking that starts with people and communities. Considering how our houses will impact the environment is an essential part of reducing global warming.

Old buildings are a finite resource and must be cared for if they are to have a future.

Regardless of the environmental issues, ancient timber-framed cottages and Georgian houses remain much sought after and, with sympathetic updating to meet the needs of today, the Victorian terrace is the twenty-first-century choice for many families. How we go about ensuring that these buildings are fit for the future and resilient to the impact of climate change is challenging, if they are to be both sustainable and retain the essence of what makes them special.

Alterations or extensions should consider the building as a whole. What might seem the most obvious way of making a house more sustainable may not always be the best way to achieve the greatest gains, and may adversely impact the building's historic context. The effects of climate change, flooding, rising temperatures, external spaces, biodiversity and the use of appropriate materials all need to be considered.

Old buildings and good new sustainable design happily co-exist.

Repair, not replacement, is a valuable way of conserving resources. Old buildings are a finite asset and we are duty bound to ensure that we are able to pass them on for the enjoyment of future generations. This is a delicate balancing act: costs and gains have to be weighed against comfort and

history, as we gain a greater understanding of how old buildings perform and can meet the challenges of low-carbon living.

Building materials and finishes are likely to suffer with extremes of climate.

Termites are capable of causing substantial damage to buildings and could become established in the UK as the climate changes.

CLIMATE CHANGE

As we experience more frequent, severe and unpredictable climatic events, there are ever greater challenges for our built environment. As well as causing direct damage to buildings, storms, flooding and intense temperature fluctuations may, over the longer term, lead to the degradation of their structure and the materials used in their construction.

This is especially likely in the case of old buildings that were not originally constructed to withstand long-term, extreme and highly variable weather cycles. Higher temperatures, combined with exceptional rainfall, will potentially affect almost every construction material and have serious implications for decay processes in the built environment. The stresses imposed may reduce the lifespan of timber joinery, cause masonry and mortar to crack and increase the likelihood of metals corroding. An

inappropriate response to these challenges could put buildings at greater risk.

External shutters are a good way of reducing solar gain.

RISING TEMPERATURES

Dry, hot summers have long been recognised as a cause of subsidence, but the threat of rising temperatures is now much more far reaching for buildings and those who occupy them. Heat is a serious threat to human health; materials and surfaces suffer through extremes of temperature and increased UV radiation; there are potential problems associated with curing mortars and, if winters are warmer, pests such as termites may become established.

Overheating in homes is the single greatest concern when considering not only comfort and health but carbon emissions and energy consumption: it costs considerably more, both in terms of energy use and cash, to cool a building than to heat it. Buildings must be adapted to keep heat in during the cold months and keep it out during warm periods. An additional benefit is that buildings which stay at an even temperature internally, and do not

fluctuate wildly, are much more comfortable than those that need strenuous control from heating and cooling systems.

Reducing overheating

Even though thermal mass helps cool buildings, it is hard for heat to dissipate once it is inside, so it is important to do everything possible to exclude it. Although closing curtains or blinds against the sun can reduce the effects of solar gain, it tends to trap a layer of hot air between the fabric and the glass, which will increase the room temperature.

External shading of south- and west-facing windows is effective in reducing overheating, as it blocks solar gain; it is also more successful than improvements to ventilation. This is why external shutters, blinds or retractable awnings are a common feature on buildings in southern Europe. Adding such features to an old building may be inappropriate although, where they have been removed in the past, they might be reinstated. To gain maximum benefit, it is important that shading is in place at sunrise.

Some buildings are designed with wide eaves to the roofs, which help to shade the windows from the high summer sun while still allowing entry to the lower winter sun to provide warmth. One relatively simple and attractive way of achieving the same result is to build a pergola in front of the ground-floor windows and then to train a vine or other similar climber along the top. This has the advantage of providing shade in the summer while still allowing plenty of light and useful solar gain to enter the house during winter when the leaves have dropped. Similarly, verandahs can shade the internal area of a house while offering semi-outdoor areas with shelter from the sun and rain.

The cases for external blinds and awnings, used to provide shading, still exist on some Georgian and Victorian buildings. This window is also fitted with internal shutters that help keep heat in during colder months.

A strategically placed deciduous tree or shrub is another means of providing natural summer shading, but it must be far enough away from the building to prevent the roots from damaging the foundations.

Ventilation has a role to play in mitigating the effects of overheating and passive systems should be considered (See Natural ventilation, shown here). Simple measures such as creating a through draught by opening windows on more than one side of a house are effective. Sash windows were

designed to provide a gap at the top to release warm air and a gap at the bottom to draw in cool air from the outside so, when properly used, they are extremely efficient in managing air flow.

Externally, reducing hard surfaces such as concrete and tarmac around the house, while increasing green areas and tree planting, as well as introducing ponds and green roofs, will help mitigate the urban heat island effect where built-up areas are significantly warmer than rural areas (See Green roofs, shown here). Trees not only provide shading but also give off moisture, resulting in cooler air entering the house.

Thermal insulation and airtightness are other factors in reducing overheating and it is worth selecting materials with good decrement delay (See Decrement delay, shown here), especially when insulating attic rooms.

Air conditioning and comfort cooling should only be considered as a last resort. Although most cooling systems are designed to be efficient, they are still energy hungry. The equipment and ductwork required take up valuable space and installation will almost certainly be damaging to the original fabric of an old house.

COLD WEATHER

Icy conditions and heavy snowfall can be hugely damaging to old buildings. Damp walls resulting from poor maintenance or the use of inappropriate materials such as cement mortars or renders may suffer frost damage, so make sure problems are rectified well before any cold weather. Frost damage to walls and roof tiles may be exacerbated by high levels of insulation that reduce heat flow through the building envelope.

Roofs and gutters must be adequate to accommodate any likely snow loading. Snow-guards fitted at the eaves will help reduce the risk of snow or ice falling and causing damage or injury, but they can be visually intrusive. Where valley or parapet gutters are present, duckboards or electric heating tape can help keep them clear and allow meltwater to escape without it seeping under the roof covering.

Phase change materials

Designed to deal with the problem of overheating, phase change materials (PCMs) store thermal energy and help to passively regulate a building's indoor climate. They are especially useful in attic rooms, as they absorb heat during the hottest part of the day and then release warmth back into the room as the temperature falls at night.

PCMs are based on a micro-encapsulated wax that changes from solid to liquid as the temperature rises, absorbing the heat and storing it latently. When the ambient temperature drops, the PCM releases the heat and the wax solidifies. Some PCMs are incorporated in clay boards, which have the added advantage of combining the thermal, acoustic and moisture-buffering qualities of the clay. Best used in ceilings but also suitable for walls, the boards can be finished with lime- or clay-based plasters. When considering their use, careful thought should be given to the potential loss of original plaster and other finishes.

Be careful to prevent salt from coming into contact with the base of walls when paths or roads are gritted, as it can lead to the decay of brick and stone.

Unstable and slender chimneys are particularly vulnerable in high winds.

STORMS AND WIND

The increased frequency of storms and extreme weather events, including strong winds and thunderstorms, poses a number of risks to old buildings. The potential for increased lightning strikes means lightning conductors become more relevant and will need to be checked more frequently. Roofs, chimneys, aerials, satellite dishes, and technologies such as solar panels must be more rigorously maintained to ensure that they are sound and secure in high winds. Trees near to buildings need to be monitored to limit the danger of falling branches or uprooting.

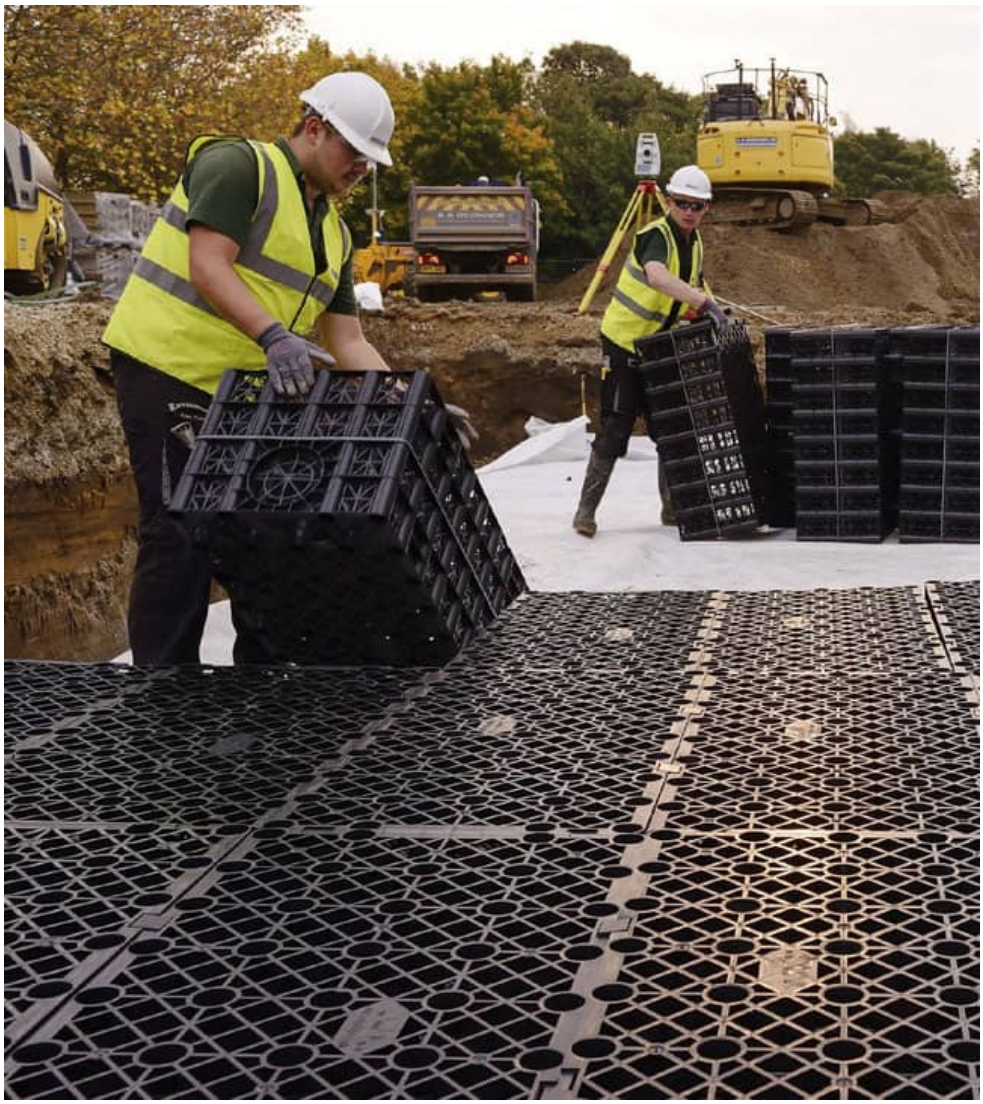
RAINFALL AND FLOODING

Extreme rainfall events, rising sea levels, coastal erosion and river surges threaten millions of homes with flooding. There is the possibility of insurers limiting or providing no cover against floods in locations that are particularly vulnerable. Heavy rain increases pressure on rainwater and drainage systems and can result in water penetration where roofs, walls, windows and other building elements are defective.

Regular inspection and maintenance is vital to deal with problems such as broken gutters, slipped tiles and blocked gutters and drains.

Driving wind and rain cause moisture penetration and dampness that may result in rot and mould growth, which can be exacerbated by insulating walls. Detailing to buildings needs to be considered. Cills, drip moulds and oversailing eaves all deflect rain, so they must not be allowed to deteriorate and, in some cases, may need to be improved to prevent damage.

Adaptations may be required to handle increased water flow. With older buildings, it is difficult to increase the capacity of rainwater systems without ruining their intrinsic character and detailing, but deeper gutters, more or larger downpipes and greater-capacity soakaways might be needed to keep the building dry. Flash flooding can occur due to drainage systems becoming overwhelmed by water run-off.



Crates are installed to provide temporary water storage as part of a stormwater management system.

Ponds are often an important element of a sustainable drainage system and provide a valuable resource for wildlife.

Sustainable drainage

Water must run away from old buildings quickly and efficiently to prevent damp problems. Where water collects around walls, a French drain is often a good solution; these invariably flow to a soakaway.

Managing surface water has become increasingly important to prevent flooding and the depletion of groundwater. The rainwater run-off from large

areas of paving or driveways is considerable. One way of dealing with this and avoiding the need for surface-water drainage is a permeable surface. Traditional materials such as gravel are ideal, as are special permeable paviours.

Extreme rainfall events place extra pressure on old buildings and gutters and downpipes often cannot cope.

These surfaces may form part of a sustainable drainage system (SuDS) designed to mitigate problems associated with rainwater run-off. A wide variety of techniques are used, including ponds and storm-water storage systems consisting of buried, hollow plastic crates where water can be temporarily held. When installing these systems, any trenches dug near existing buildings must be far enough away to avoid affecting the stability of the structure.

Designing for flooding

Although the cause of flooding is often out of your control, increasing a building's flood resistance and flood resilience will lessen the impact. Flood resistance involves physical barriers that stop, or at least minimise, the amount of floodwater entering the house. Flood resilience is about adapting a building to limit the damage if water does enter, thus speeding up drying times and re-occupation.

The use of appropriate materials is crucial. Breathable, traditional materials have the advantage that, although they absorb water, they generally dry out without losing their integrity. In contrast, modern gypsum plasters and plasterboard break down when damp and have to be replaced. Cement, water-repellent coatings, sealants and damp-proof membranes prevent the drying-out process.

Flood resistance measures:

- De-mountable barriers or flood doors to delay water entering the building – but consider the practical and aesthetic damage they may do to an old house. Bear in mind that they may also trap water inside.
- Removable air vent and service point covers or wraparound 'skirts'. Water that gains access to the void beneath a suspended timber floor will potentially come up through the floorboards.
- Sealing gaps and holes to prevent water ingress but using materials and techniques sympathetic to the structure.
- Fitting non-return valves to drainage systems to prevent sewage and foul water entering the building.

Flood resilience measures:

- Breathable materials: renders, plasters and pointing.
- Electrical, heating (including boilers) and other essential equipment sited on upper floors or protected. This is necessary for the drying-out process and the ability to start using the building again.
- Electrical consumer units installed on upper floors.
- Electric cables running from ceiling level rather than up from under the floor. Potential damage to the historic fabric if walls have to be chased must be considered.
- Power sockets positioned above likely flood levels.
- A breathable floor, if replacing a concrete floor (See Limecrete floors, shown here).

Flooding poses a risk to many homes and can come unexpectedly.

In flood-risk areas, permanent flood prevention measures may be required.

Sprinkler systems

Although automatic sprinkler systems have long been used in buildings for fire protection, they are sometimes seen as difficult, damaging and expensive to retrofit. Mist systems have been designed to overcome these problems and are claimed to provide the same performance, but typically use 90 per cent less water, minimising the potential for water damage to the building's fabric and contents.

Mist systems relocate the traditional spray heads from the ceiling to a wall-mounted nozzle and use a rotating head that directly targets the fire with a powerful jet of water mist. Water is taken straight from the mains and pumped through a flexible hose to the head. The pump requires little space and the pipework is potentially relatively easy to thread through the fabric of the building. Consequently, they can be useful in meeting building regulations, particularly in the case of loft conversions and open-plan houses and flats. These systems can overcome the need for other more invasive fire protection measures.

Rotating heads directly target the source of the fire with water mist.

The pumps used with mist systems are designed to feed a number of heads.

FIRE

Alarm and monitoring systems are essential to give early warning of fire (See Warning systems, shown here) and, wherever possible, appropriate measures should be introduced to reduce the risk of fire and to provide a means of escape. Use fire-rated materials and, wherever practical, compartmentalise the building, paying particular attention to attics and unoccupied roof spaces which often allow the rapid spread of fire through the building. All service penetrations must be fire stopped (See Fire

stopping, shown here). Where lofts are being converted to habitable space, it may be necessary to upgrade doors to provide fire separation. Careful design is needed to minimise the impact on historic fabric as these measures are often difficult to implement sensitively in old buildings. Voids behind panelling, for example, are particularly problematic. Special measures may be needed for thatched houses and, in all cases, good maintenance of chimneys and electrical systems is vital.

Measures to reduce the risk of fire are particularly important in thatched houses.

DESIGNING FOR THE FUTURE

Respect and understanding are key when working with old buildings. Our built heritage is finite and learning how to adapt it sympathetically is vital. We have already seen what the plastic and double-glazing window salespeople have done to the faces of so many houses, but the consequences of a concerted drive to retrofit buildings without understanding them is a greater long-term threat.

Drying racks save on the energy that would be used by tumble-dryer

In designing for sustainability it is important not to over-complicate matters and place reliance on systems and details that can fail if not installed correctly. Simple is generally best when working with old buildings. Houses must be easy and intuitive to use, as well as comfortable and adaptable to changing needs. With the elderly and those who are less able, thought must be given to making buildings more accessible without damaging their character or how they work.

Houses that are versatile and able to cope with the changing dynamics of family life and an ageing population are enduringly popular. This is worth

bearing in mind when buying or renovating an old building, because making it adaptable will allow it to be more sustainable in the long term. Wherever possible, plan ahead so that work does not have to be undone in the future, which will result in added costs, wasted materials and ongoing damage to the building's fabric.

Always try to incorporate measures that will help save energy and money. For example, traditional clothes-drying racks do not look out of place in an old house and save the use of an energy-hungry tumble-dryer. If possible, site the rack so that it can make use of warm air from a south-facing window or a radiator, but ensure it has sufficient ventilation so the moisture from damp clothes does not cause condensation (See Planning the interior, shown here).

Good design that maximises natural light helps make old buildings fit for the future.

INTRODUCING DAYLIGHT

Dark interiors are not uncommon in old buildings, especially when internal layouts have been rearranged. Bringing in daylight will reduce the need for artificial lighting, but careful thought should be given to how best to achieve this.

Rooflights

Modern rooflights tend to look incongruous in old buildings, as they stand proud of the slates or tiles. Far more acceptable are ‘conservation rooflights’, which are set flush with the pitch of the roof and often incorporate a central glazing bar to imitate early cast-iron versions.

Rooflights should be carefully planned to have minimum impact on an old roof.

A large range of rooflights is available, so check the specification carefully and consider how the design will work visually on your roof. Thermal bridging can be a problem with rooflights and condensation may occur. Ask the manufacturer about these issues and select a product that provides the best thermal specification. Plan the position of the opening so that the minimum number of rafters have to be cut.

EXTENSIONS

Before extending, think how existing spaces within the building can be better employed. This solution will potentially use fewer natural resources and may be less detrimental to the external appearance of the building; for example, loft spaces are often successfully converted, as are basements and

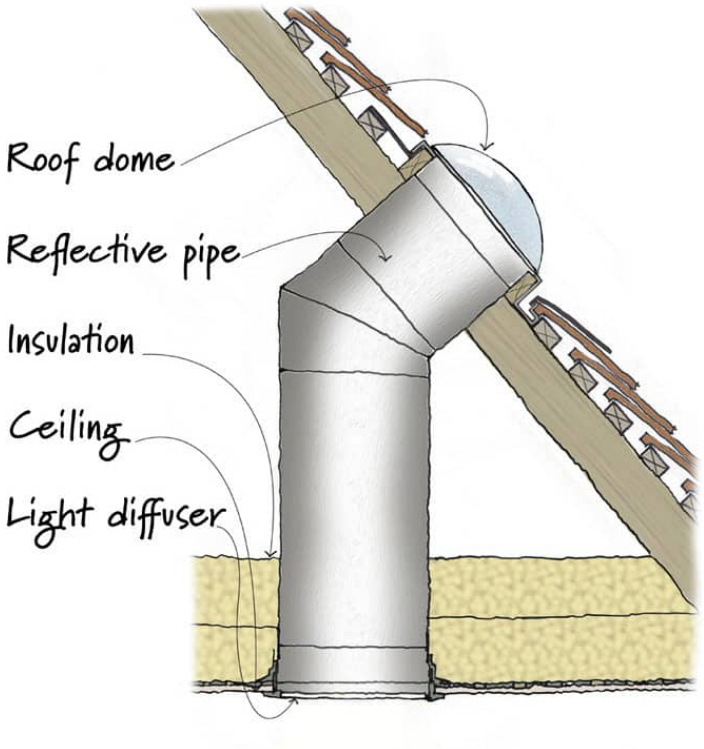
cellars. But bear in mind the limitations of these spaces and the impact this will have on the rest of the house. Rather than putting unnecessary pressure on an old building, a better option may be to create a separate room in the garden. These are often available in kit form or are built off site and craned into position with minimal disruption. Ultimately, if you move, many designs have the benefit that the room can be relocated to your new home.

Careful planning is essential when adding an extension. Consider how the extra space will work with the existing building and how you will circulate within it. It is very easy for the room from which an extension is built off to become a corridor, with the result that little useful space is gained. Maintaining natural light and ventilation to the original house is crucial. Creating rooms that need to be lit by artificial light or ventilated mechanically increases energy consumption and may make the space feel claustrophobic. Think about installing rooflights or sun tubes to bring daylight into the interior. Staircases and light wells are good ways of introducing natural light. When building an extension, remember that it is unlikely to be upgraded for many years, so always build to the highest specification possible, especially when it comes to thermal insulation and airtightness. Bear in mind that the original structure needs to breathe and, if this is compromised by the extension, damp and other problems may develop. An impermeable modern floor should not be laid adjacent to an old breathable one and, where an old house has suspended timber floors, ensure that the underfloor ventilation is not blocked (See Suspended timber floors, shown here).

Sun pipes

Sun pipes or tubes are a way of bringing natural light into the heart of a building, although it is important to consider their visual impact both at roof level and within the room where they emerge. They are particularly suitable on double-pitch roofs, where they can be hidden in the central valley.

In many cases the tubes will fit between existing rafters and joists, but care needs to be taken over their exact path to ensure that minimum damage is caused to the building's fabric. Routes from the top of the tube to the internal diffuser need to be kept as short and straight as possible: 10 per cent of usable light is lost at every bend. Smooth-sided tubes are said to offer superior performance. A south-facing roof is the optimum position for the dome and, if sited on a north face, it should be positioned as high as possible. When used in a prominent position, a conservation version is available with a flat top rather than a dome.



Sun pipes offer a way of introducing natural light.

The impact of a sun pipe's dome on the roof must be considered.

Try to design an extension so that minimum damage is caused to the historic fabric of the existing building. This is particularly important when it comes to deciding how to access the new space from the old. If possible, avoid knocking holes in original walls and use existing window or door openings instead.

Differential movement must be considered. Problems can occur when a new extension with deep foundations is attached to an old building with shallow foundations, so ensure that the junction between the two is designed appropriately.

Conservatories

Conservatories were a Victorian invention, so they may look out of place aesthetically with buildings of earlier periods. Adding a conservatory raises the same issues as any other type of extension, but there are additional considerations. By their very nature, conservatories can be too hot or too cold due to the area of glass that they contain, so they may result in high energy use for heating and cooling. Try working with the positives of a conservatory, utilising solar gains in winter and insulating against the loss

of heat at night by shutting insulated doors at the conservatory's entrance into the house. In the summer, blinds are essential.

The conversion of a formerly derelict dairy building by Harrison Brookes Architects into a home included a green oak frame extension providing a glazed garden room.

New basements

Digging out a basement under an old house adds space but is a major intervention and should not be undertaken lightly. Constructing a basement can result in damage and cracking to the fragile fabric of an old house. In addition, because the new basement effectively acts as underpinning, differential movement may occur between adjoining houses where one has the rigidity created by the basement and the other has shallow foundations. Invariably the new structure is tanked to make it waterproof. While this keeps the basement dry, the displaced moisture may be forced up and outwards, creating damp problems in the walls above.

From an environmental perspective, the disposal of the soil from the excavations and the lorry movements required should be considered.

Extensions: key issues

Think carefully about how an extension can be made to work with the character and architectural rhythm of the original building, while being as sustainable as possible in its construction and future performance:

- Aim for good new design, keep it simple and avoid poor pastiche.
- Consider circulation and how the rooms that connect with the extension will be used in the future.
- Maximise daylight and ventilation into the original building as well as the extension.
- Use materials that are natural, sustainable and local.
- Achieve the highest levels of insulation and airtightness possible.
- Fit high-performance glazing in a style that enhances the original building.
- Think about future maintenance and how areas of the existing building, such as gutters and windows above, will be accessed once the extension is built.
- Link to the outside so that the garden and landscape becomes part of the space.

An extension, designed by Malcolm Fryer Architects, to a Grade II listed early Victorian townhouse provides flexible family accommodation and a large office space with a green roof. The distinctive two-storey contemporary addition includes a bathroom glazed to provide a luminous bathing experience overlooking the garden.

LOW-IMPACT MATERIALS

Many traditional building materials have a low environmental impact and some manufacturers have brought them full circle, adapting them to suit today's requirements. Using these materials and products can sometimes require determination to get them through building control, and builders may have to be persuaded to use and understand them. Perseverance can

bring considerable gains in aesthetics, comfort, wellbeing and energy savings.

Compressed earth blocks, hempcrete blocks and clay boards are among the sustainable building products being produced which, along with straw bales, can be used to build new structures while also being compatible with the breathable nature of traditional buildings.

Clay products

An ancient building material, clay is not only natural and healthy but also adds to a building's thermal mass and passively helps to optimise the relative humidity of the internal climate by acting as a moisture buffer. Clay products are durable, repairable, return to earth at the end of their life and are low in embodied energy.

Structural blocks of clay-rich earth and chopped straw, dried rather than fired, can be used for internal and external load-bearing walls. They are bedded in clay mortar, creating a homogenous earth wall.

Structural blocks formed of unfired clay.

Clay boards offer many useful properties when used for dry-wall construction.

If properly constructed and kept dry, walls built of straw bales are an excellent building material, offering good thermal properties. Here, lime render is being applied by spraying.

Clay boards offer good sound absorption qualities. Providing an alternative to gypsum plasterboard, they are used internally for drywall construction and are finished in a clay or lime plaster. Clay plasters are available in a range of colours, so no extra painting is required, and are useful in rooms with high humidity and where flexibility is required. As well as being used with clay substrates, they may be applied internally to a variety of traditional materials.

GREEN ROOFS

Constructed over flat or shallow pitched roofs, green or living roofs take various forms, often consisting of sedum or indigenous wildflowers, herbs

and meadow grasses. As well as giving visual pleasure, they offer a number of environmental benefits:

- Increasing biodiversity by providing a habitat for wildlife.
- Temporarily storing water during a storm, so that its run-off is attenuated to prevent flash flooding.
- Protecting the roof covering from the sun.
- Providing thermal and acoustic insulation to the building.
- Improving air quality, especially in cities.

Depending on their structure and design, the flat roofs of some Georgian and Victorian town houses may be suitable for green roofs, so it is worth considering the possibilities, especially when installing new roof coverings. One of the advantages of some modular green roofing systems is that they are, to varying degrees, removable in the future should it be necessary to put the roof back to its original state.

Eco roof coverings

When extending an old house, consider the environmental credentials of the roofing materials that you opt for. Beside green roofs, thatch is top of the list of eco coverings. Locally grown straw or reed is sustainable, has low embodied energy and is fully biodegradable. If detailed properly, it can meet required U-values without the need for further insulation. Hand-split shingles offer a more contemporary roof covering and also come from a sustainable source with low embodied energy, providing the timber is not non-traditional, imported cedar.

Green roofs provide an excellent covering to flat-roofed extensions.

The choice of plant species will influence the type of wildlife attracted to a green roof.

Green roofs: key issues

Weight is the main issue with green roofs. As well as the dry weight of the growing medium and plants, thought has to be given to the added burden of retained water and snow. On an old roof, this may be too much of a strain. Wind loading must also be addressed. An assessment by an engineer is essential.

When selecting contractors and suppliers for a green roof installation, ensure they have the necessary level of competence in roofing and horticulture – not all specialists have expertise in both fields. Discuss with them what you hope to achieve: the choice of roof and plant species will influence the type of wildlife it attracts and its impact on the building.

Lichens are just part of the biodiversity linked to buildings.

A green roof does not replace the roof covering and there must be a continuous waterproof membrane underneath. It cannot be installed directly onto a metal roof or any other jointed roof type, as the joints will be vulnerable to moisture ingress by capillary action. Despite the potential thermal benefits of a green roof, additional insulation is still likely to be required.

Although some water is retained by a green roof, gutters and downpipes are needed to deal with water run-off, and drainage from other existing roofs that run on to the green roof must be taken into account. It is essential that the growing medium and plants do not block gutters. At the edges, the flashing along parapet walls and around chimneys must be high enough to prevent moisture penetrating the masonry. It is generally advisable to leave a space between the vegetation and the edges of the roof and walls to allow for adequate drainage. This is usually filled with shingle or pebbles.

Access for ongoing maintenance is vital, whatever type of green roof is installed. Water will need to be supplied for irrigation if this should become necessary.

BIODIVERSITY

Over 620 species of lichens have been recorded on built structures in Britain. Buildings and their immediate surroundings can provide environments for a huge range of flora and fauna. The decline of some species may be due, at least in part, to the loss of the valuable habitat provided by nooks and crannies in both old and new buildings.

The spaces around buildings can contribute to biodiversity and are important to human wellbeing, particularly in urban areas. Vegetation acts as an air purifier, a carbon store and a food source in the form of nuts, fruits and berries. Trees, hedges and even banks of earth may provide a windbreak or shade and can help reduce the threat of flooding.

WILDLIFE AND BUILDINGS

Many species are protected by law. The presence of birds, bats, beetles, toads, newts, snakes and snails can stop or slow building work. Ignoring their presence may land you in court.

Old buildings are potentially a haven for wildlife. Monitoring may be required before starting work when protected species are involved.

When a protected species is discovered or suspected, specialist monitoring may be required to gather data to make informed decisions. This could mean re-homing or adhering to seasonal restrictions – for example, by carrying out work only when breeding or hibernation is not taking place. Inevitably there will be costs involved and these should be factored into budgets when planning work.

Bats

All species of bat found in the UK are protected by law. Bats return to their roost year after year, and are found in roofs and under hanging tiles or cladding. Signs of their presence include dark brown 4–8 mm long droppings that crumble to a powder when dry.

Protected by law: lesser horseshoe bats in a roof space.

The roost is legally protected, even if the bats do not appear to be there. If work needs to be undertaken that might affect them – including the treatment of wasps' nests, roof repairs, re-wiring or plumbing – you should seek advice at the earliest opportunity from your local Statutory Nature Conservation Organisation (SNCO).

To encourage bats, a variety of bat boxes are available that can be fixed to buildings or built into the structure.

Birds

Buildings are important for a number of bird species, especially swallows, house martins and swifts, as well as house sparrows, starlings, barn owls and even peregrine falcons. In the UK, all wild birds, their nests and their eggs are protected by law. Think carefully before re-tiling roofs or installing

insulation that may block entry points and, wherever practical, introduce nesting places. This has to be balanced with the fact that birds can sometimes be a nuisance as their droppings may deface facades and their nests can block essential pipework and flues.

When deterring birds, take the minimum measures necessary and remember that these are sometimes more intrusive than the presence of the birds themselves. Fit cages to the tops of soil stacks and chimneys to prevent them from being blocked by nests. Where birds perching on ledges presents a problem, plastic spikes may be a solution. An alternative is a ‘fire-gel’ repellent that birds see as ultra-violet light, making it appear like fire. This deters them from returning to sites they have previously inhabited.

Masonry or mortar bees have burrowed into this cob wall.

Bees

Masonry or mortar bees burrow through soft, usually earth-mortar joints, stone, bricks or earth structures such as cob walling, usually on the south elevation that has been warmed by the sun. The female constructs tunnels to form brood chambers. The young bees emerge in summer but continue to inhabit the wall until the following spring when they, in turn, make further tunnels. A single bee will not usually cause any significant problem, but as the numbers increase over the years the damage may become more severe.

Raking out and repointing, which is best done during late summer or autumn, will usually deter masonry bees. To avoid damaging the building, a weak lime mortar should be used. Where larger surfaces are affected, the solution may be to lay a fine plastic mesh carefully over the area used by the bees each year and encourage them to find a new home. This approach may be required for a couple of summers but eventually does break their cycle.

SUSTAINABLE LIVING

Carefully retrofitted old buildings have the potential to be at the heart of a sustainable lifestyle. Even so, the most eco old house will fail to meet its full potential if the occupants do not understand how it works and fail to use and care for it appropriately. All houses have idiosyncrasies, but making a note of potential issues, dealing with them swiftly and appropriately, and being assiduous with routine maintenance pays dividends.

When the time comes to move on and hand over the guardianship of the property to someone new, try to help them understand its quirks as well as what makes it a comfortable, interesting and sustainable building.

A house book is a good way of keeping a record of what has been done, together with relevant information on the systems and technology installed. Include notes on the insulation, airtightness, heating and ventilation strategies, and the materials and products employed. Note the breathable nature of the building and if, for example, a limewash has been applied, explain its advantages and why this finish must be used going forward, rather than a modern ‘plastic’ paint.

The spaces around buildings are important to human wellbeing and are useful in creating biodiversity.

Sense of place

Communities are central to creating sustainable environments, because places with a strong community are good places to live; they are interesting, build human interaction and are safer and more secure. As a result, they tend to be less demanding of resources and wasteful redevelopment is less likely.

Retaining existing buildings does more than save wasteful replacement; it maintains the traditional urban and rural landscapes and the communities that lie within.

The character, layout and grouping of buildings in the past has frequently contributed to a sense of place. Business owners used to live above the shop so did not commute to work over long distances. Traditionally, communities were a mix of ages and were strongly rooted in context, both physical and cultural.

There are many good examples of this – almshouses and collegiate settings, for instance, where the grouping of properties around formally defined courtyards promotes an atmosphere of order, and helps to balance the occupants' desire for privacy and independence with a reassuring sense of community and security.

Places where people feel secure tend to have longevity and are therefore sustainable. One of the reasons bay windows achieved popularity in the 1870s was that they provided views of the street that were unavailable with ordinary windows. We may associate this with Victorian nosiness but, when

it comes to making a neighbourhood safe and secure, the person looking out from a bay window is a far more desirable option than a CCTV camera.

Vibrant places improve local economic performance, enhance and support biodiversity, enable healthy living and foster local pride and community cohesion. People feel rooted in their surroundings, maintain their homes and know and care about their neighbours.

Environmental benefits come from social, interactive processes such as car sharing, local food networks and people working together on allotments.

Conversely, soulless buildings that hinder the ability of inhabitants to interact with one another, and that are surrounded by hard surfaces with no public spaces, lack a sense of community, are difficult to love and are apt to be less secure. This absence of a real connection to a place means people take less care of it and are likely to move house more regularly, further destroying the sense of community cohesion.

Good design coupled with buildings that have retained their character, history and roots bring out the best in human nature, encourage and create convivial places and result in sustainable communities.

Buildings that have retained their character, history and roots, such as this Sussex farmhouse and its associated outbuildings, bring out the best in human nature. Balancing the needs of the future with the legacy of the past is a big challenge for the next generation.

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MARIANNE SUHR, ROGER HUNT

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Dedication
For the generation who will inherit our successes as well as our mistakes
Charlie, Max and Ben MARIANNE SUHR
Nick, Annie, Kate and Eppie ROGER HUNT

In memory of Neil May 1962–2018
Through his deep knowledge and understanding, Neil played a pivotal role in forging links between the green building movement, building conservation professionals and government. Neil spoke passionately and persuasively about the unintended consequences of incompatible retrofitting techniques and materials, and his words influenced policy and practice. We miss his wisdom and his infectious enthusiasm.

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